A READER IN BOTANY

NEWELL

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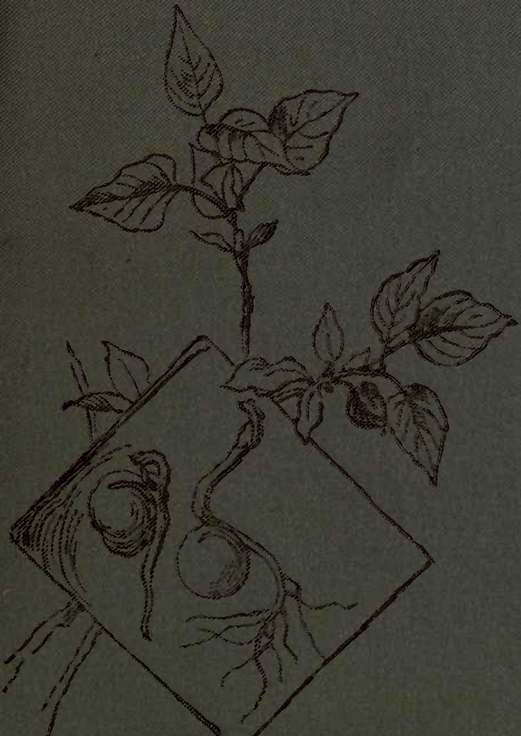
PART I.



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A

READER IN BOTANY.

Part I.

FROM SEED TO LEAF.

SELECTED AND ADAPTED FROM WELL-KNOWN AUTHORS,

BY

JANE H. NEWELL.

BOSTON, U.S.A.:
GINN & COMPANY, PUBLISHERS.
1895.

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PREFACE.

THE purpose of this book is to supply a course of reading calculated to awaken the interest of the pupil in the study of the life and habits of plants. It is not to be judged as a complete work in itself, but as a series of articles bearing on the subjects of the lessons described in "Outlines of Lessons in Botany."[1]

Four of the articles, Nos. II., III., XIII., and XV., have been written especially for this Reader. Three articles are translated from "Pflanzenleben,"[2] and two others owe much of their matter to the same book, which is a very charming popular account of the most recent discoveries in the physiology of plants. The other chapters are from various sources.

Sachs' "Lectures on the Physiology of Plants"[3] has supplied several interesting notes, and is an invaluable work to the teacher who wishes to become more acquainted with this fascinating new field of study.

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[1] "Outlines of Lessons in Botany." By Jane H. Newell. Boston: Ginn & Co. 1889.

[2] "Pflanzenleben." By Anton Kerner von Marilaun. Leipzig. 1888.

[3] "Lectures on the Physiology of Plants." By Julius von Sachs. Translated by H. Marshall Ward. Oxford, 1887.

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A READER IN BOTANY.

I.

ORIGIN OF CULTIVATED PLANTS.

All our food comes through plants. They are the link between the animal and mineral kingdoms. They are able to take from the earth and the air the inorganic substances they require, and to build them into organized material on which animals can live. Directly, through the use of the plants themselves, and indirectly, through animals which have been nourished by plants, we get all our food through the vegetable kingdom.

Many of our fine varieties of garden vegetables and flowers have been produced in the following way: —

The gardener sows seed of his best plants, and selects from the offspring those which best show the characters he wishes to increase. From the offspring of these he again selects the best, and so on, through many generations, till the fine color, or sweet taste, or great size, he has been working towards, becomes perfected. Then these improved plants can be multiplied by grafts, buds, or cuttings, which usually transmit the exact qualities of the parent, until the variety is well established. The seedlings of a plant have a tendency to inherit the characteristics of the parents, and also to vary somewhat. By selecting, through a long series of generations, individuals tending towards a certain desired character, and allowing the less desirable to perish, distinct varieties are produced. In this, man has unconsciously followed the process of Nature herself, who through long ages has been improving her work by suffering her weaker and poorer children to perish, through their lack of power to compete with those better suited to their surroundings. The latter survive and hand down their qualities to their offspring, whose descendants in their turn, best adapted to take advantage of their opportunities, usurp the room, which is not wide enough for all.

With animals the process is the same. The wonderful speed of the trotter, the pointing of the hunting-dog, the direct flight of the carrier-pigeon towards home, are all instincts that have been developed by man by the same process of selection. Darwin[1] says: —

"From a remote period, in all parts of the world, man has subjected many animals and plants to domestication or culture. Man has no power of altering the absolute conditions of life; he cannot change the climate of any country; he adds no new element to the soil; but he can remove an animal or plant from one climate or soil to another, and give it food on which it did not subsist in a natural state. . . . Although man does not cause variability and cannot even prevent it, he can select, preserve, and accumulate the variations given to him by the hand of nature, in any way that he chooses; and thus he can certainly produce a great result. Selection may be followed either methodically and intentionally, or unconsciously and unintentionally. Man may select and preserve each successive variation with the distinct intention of improving and altering a breed, in accordance with a preconceived idea; and by thus adding up variations, often so slight as to be imperceptible to an uneducated eye, he has effected wonderful changes and improvements. It can also be clearly shown that man, without any intention or thought of improving the breed, by preserving in each successive generation the individuals which he prizes most, and by destroying the worthless individuals, slowly, though surely, induces great changes. As the will of man thus comes into play, we can understand how it is that domesticated breeds show adaptation to his wants and pleasures. We can further understand how it is that domestic races of animals and cultivated races of plants often exhibit an abnormal character, as compared with natural species; for they have been modified not for their own benefit, but for that of man."

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[1] "The Variation of Animals and Plants under Domestication." By Charles Darwin. New York. D. Appleton & Co. 1887. Vol. I. p. 2.

Until quite lately, the origin of almost all cultivated plants was completely unknown. M. Alphonse De Candolle investigated the subject very thoroughly, publishing his first results about thirty years ago. In a recent review of the whole subject[1] he gives a list of two hundred and forty-seven species of cultivated plants, with their geographical origins, and the number of centuries or thousands of years during which each has been cultivated, as far as can be known. He says:[2]

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[1] "Origin of Cultivated Plants." By Alph. De Candolle. New York. D. Appleton & Co. 1885.

[2] Page 1.

"The traditions of ancient peoples, embellished by poets, have commonly attributed the first steps in agriculture and the introduction of useful plants, to some divinity, or at least to some great emperor or Inca. Reflection shows that this is hardly probable, and observation of the attempts at agriculture among the savage tribes of our own day proves that the facts are quite otherwise.

"In the progress of civilization the beginnings are usually feeble, obscure, and limited. There are reasons why this should be the case with the first attempts at agriculture or horticulture. Between the custom of gathering wild fruits, grain, and roots, and that of the regular cultivation of the plants which produce them, there are several steps. A family may scatter seeds around its dwelling, and provide itself the next year with the same product in the forest. Certain fruit trees may exist near a dwelling without our knowing whether they were planted, or whether the hut was built beside them in order to profit by them. War and the chase often interrupt attempts at cultivation. Rivalry and mistrust cause the imitation of one tribe by another to make but slow progress. If some great personage command the cultivation of a plant, and institute some ceremonial to show its utility, it is probably because obscure and unknown men have previously spoken of it, and that successful experiments have been already made. A longer or shorter succession of local and short-lived experiments must have occurred before such a display, which is calculated to impress an already numerous public. It is easy to understand that there must have been determining causes to excite these attempts, to renew them, to make them successful.

"The first cause is that such or such a plant, offering some of those advantages which all men seek, must be within reach. The lowest savages know the plants of their country; but the example of the Australians and Patagonians shows that if they do not consider them productive and easy to rear, they do not entertain the idea of cultivating them. Other conditions are sufficiently evident: a not too rigorous climate; in hot countries, the moderate duration of drought; some degree of security and settlement; lastly, a pressing necessity, due to insufficient resources in fishing, hunting, or in the production of indigenous and nutritious plants, such as the chestnut, the date-palm, the banana, or the bread-fruit tree. When men can live without work, it is what they like best.

Besides, the element of hazard in hunting and fishing attracts primitive, and sometimes civilized, man, more than the rude and regular labor of cultivation."

Darwin gives us in the book quoted above an excellent idea of the beginnings of agriculture.[1] "MM. Loiseleur-Deslongchamps and De Candolle have remarked," he says, "that our cultivated plants, more especially the cereals, must originally have existed in nearly their present state; for otherwise they would not have been noticed and valued as objects of food. But these authors apparently have not considered the many accounts given by travellers of the wretched food collected by savages. I have read an account of the savages of Australia cooking, during a dearth, many vegetables in various ways, in the hopes of rendering them innocuous and more nutritious. Dr. Hooker found the half-starved inhabitants of a village in Sikhim suffering greatly from having eaten arum-roots, which they had pounded and left for several days to ferment, so as partially to destroy their poisonous nature; and he adds that they cooked and ate many other deleterious plants. Sir Andrew Smith informs me that in South Africa a large number of fruits and succulent leaves, and especially roots, are used in times of scarcity. The natives, indeed, know the properties of a long catalogue of plants, some having been found during famines to be eatable, others injurious to health, or even destructive to life. He met a party of Baquanas, who, having been expelled by the conquering Zulus, had lived for years on any roots or leaves which afforded some little nutriment, and distended their stomachs so as to relieve the pangs of hunger. Sir Andrew Smith also informs me that on such occasions the natives observe as a guide for themselves, what the wild animals, especially baboons and monkeys, eat.

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[1] Vol. I. p. 324,

"From innumerable experiments made through dire necessity by the savages of every land, with the results handed down by tradition, the nutritious, stimulating, and medicinal properties of the most unpromising plants were probably first discovered. It appears, for instance, at first an inexplicable fact that untutored man, in three distant quarters of the world, should have discovered among a host of native plants that the leaves of the tea-plant and mattee, and the berries of the coffee, all included a stimulating and nutritious essence, now known to be chemically the same.

We probably owe our knowledge of the uses of almost all plants to man having originally existed in a barbarous state, and having been often compelled by severe want to try as food almost everything which he could chew and swallow.

"From what we know of the habits of savages in many quarters of the world, there is no reason to suppose that our cereal plants originally existed in their present state so valuable to man. Let us look to one continent alone; namely, Africa. Barth states that the slaves over a large part of the central region regularly collect the seeds of a wild grass, the *Pennisetum distichum;* in another district he saw women collecting the seeds of a Poa by swinging a sort of basket through the rich meadow-land. Near Tete, Livingstone observed the natives collecting the seeds of a wild grass; and farther south, as Anderson informs me, the natives largely use the seeds of a grass of about the size of canary seed, which they boil in water. They eat also the roots of certain reeds; and every one has read of the Bushmen prowling about and digging up with a fire-hardened stake various roots. Similar facts with respect to the collection of the seeds of wild grasses in other parts of the world could be given.

"Accustomed as we are to our excellent vegetables and luscious fruits, we can hardly persuade ourselves that the stringy roots of the wild carrot and parsnip, or the little shoots of the wild asparagus, or crabs, sloes, and so forth, should ever have been valued; yet from what we know of the habits of Australian and South African savages, we need feel no doubt on this head. The inhabitants of Switzerland, during the stone period, largely collected wild crabs, sloes, bullaces, hips of roses, elderberries, beech-mast, and other wild berries and fruits. Jemmy Button, a Fuegian on board the Beagle, remarked to me that the poor and acid black currants of Terra del Fuego were too sweet for his taste.

"The savage inhabitants of each land, having found out by many and hard trials what plants were useful, or could be rendered useful by various cooking processes, would after a time take the first step in cultivation by planting them near their usual abodes. Livingstone states that the savage Batokas sometimes left wild fruit trees standing in their gardens and occasionally even planted them, 'a practice seen nowhere else among the natives.' But Du Chaillu saw a palm and some other wild fruit trees which had been planted; and these trees were considered private property. The next step in cultivation — and this would require but little forethought — would be to sow the seeds of useful plants; and as the soil near the hovels of the natives would often be in some degree manured, improved varieties would sooner or later arise. Or a wild and unusually good variety of a native plant might attract the attention of some wise old savage; and he would transplant it, or sow its seed."

II.

THE COTTON PLANT.[1]

By Nina Moore.

Cotton, like wheat, is older than history. In the time of Herodotus, and probably long before, the people of India wove the fibre of their native species, *Gossypium arboreum,* into garments; for centuries they cultivated around the Hindoo temples *Gossypium religiosum,* reserving its product for the tripartite thread, which, as a symbol of the Brahmin Trinity, was used in the sacerdotal robes of the priests.

India muslins are famed for their beauty. Tavernier (1662) says that some of the muslins or

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[1] This classification of the species of *Gossypium,* founded on that of Linnæus, is given by Parlatore in his "Le Specie dei Cotoni."

Gossypium Arboreum; native of India.
" Herbaceum.
" Religiosum.
" Barbadense: sea island, long-stapled cotton; native of the Bahama Islands.
" Hirsutum: Georgia, upland, short-stapled cotton; native of Mexico.
" Sandvichensis; native of the Sandwich Islands.
" Taitensis; native of Tahiti.

"calicuts"[1] that he saw were "so fine that you could hardly feel them in your hand." The Rev. William Ward goes further yet, and describes a fabric "so exceeding fine that when laid on the grass and the dew has fallen on it, it is no longer discernible." The looms from which these marvellous webs emerged were of the most primitive sort; yet when they disappeared, under the ad-

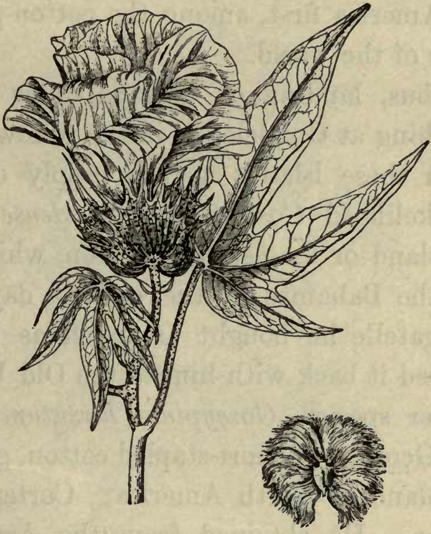

FIG. I. GOSSYPIUM BARBADENSE (Royle).

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[1] Calicut was a town on the Malabar coast, whence cotton cloth was imported. Our word *calico* is a corruption of the name.

vance of English machinery, the skill of the people became almost a thing of the past, the new industry having quite obliterated the old.

Abundant as India's cotton crop has always been, that of America surpasses it. India stands second, America first, among the cotton-producing countries of the world.

Columbus, landing on San Salvador in 1492, and touching at Guadeloupe in the following year, found on these islands a rich supply of cotton, in all likelihood *Gossypium Barbadense* (Fig. 1), the sea-island or long-stapled cotton, which grows wild on the Bahamas at the present day. For a mere bagatelle he bought as much as he could, and carried it back with him to the Old World.

Another species, *Gossypium hirsutum* (Fig. 2), Upland, Georgia, or short-stapled cotton, grew upon the mainland of North America. Cortez found it in Mexico. He obtained from the Aztecs good cloth of their own manufacture, and sent home to Charles V., of Spain, "cotton mantles, some all white, others mixed with white and black, or red, green, yellow, and blue."

These long-staple and short-staple cottons, *Gossypium Barbadense* and *Gossypium hirsutum*, of the Bahamas and of Mexico, were early introduced into Virginia and Georgia. It was in 1621 that some cotton seeds, probably of *Gossypium Barbadense* from the West Indies, were planted in Virginia as an experiment. In 1739 a Swede named Samuel Auspourguer, who had cultivated cotton in Georgia, carried a sample of his fibre to England. After that, small but increasing quantities were sent over yearly until cotton became the most important export of the South.

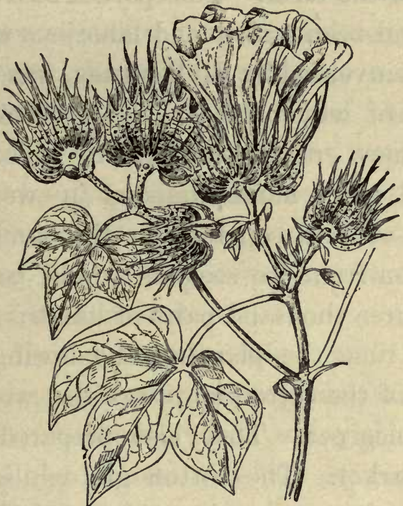

FIG. 2. GOSSYPIUM HIRSUTUM (Royle).

In 1792 the cotton sent from the United States to Liverpool amounted to 138,328 pounds. In

1794 the amount rose to 1,601,700 pounds. The cause of this tremendous increase, and the still greater increase that followed, was the invention, in 1793, of the cotton gin.

The cotton fibre grows on the seed, and is firmly adherent to the testa. To separate seed and fibre by hand had been a slow and laborious task. The cotton gin, invented by Eli Whitney, was a machine by means of which, as Mr. George Emerson has said, "a new era in the culture of cotton was established, three hands assisted by water power being now able to separate, in the same time, as much cotton from its seed as would before have required three thousand pairs of hands."

At that time the planting, the hoeing, and the gathering of the cotton crop was the work of the Southern negroes. They also prepared the fibre for the market. The cotton gin, while relieving them of the latter task, increased the demand for their services in the fields; for, as immense quantities of cotton could now be furnished to all parts of the United States and Europe, a large supply must be sown and tended. It was a striking instance of the action of machinery in cutting down the sum of hand labor required at one point only to raise it an hundred-fold at another. Field-hands were in great demand, and the immediate effect of the invention of the cotton gin was the tightening of the bonds of the slave. Slave labor became all in all to the planters of the South. Northern men were afraid to meddle in the interest of humanity when the interests of King Cotton were at stake. It was declared, and came to be believed, that negro labor only was available in those blazing cotton fields, and that only as slaves could negroes be forced to work. Events have abundantly proved, however, that free labor is not injurious to cotton; white men, as well as negroes, are now employed in its culture, and the crop is larger than ever.

In the United States census report for 1884, Mississippi stands first among cotton-producing States. Its particularly rich soil yields cotton at the rate of eight-tenths of a bale per capita yearly.

Both kinds of cotton, the long-stapled and the short-stapled species, are planted in Mississippi. As soon as the frost is out of the ground the cotton stalks of the preceding year are knocked down and cleared away, or sometimes burned and plowed under. The field is then scored in long furrows, four or five feet apart in the best soil, where the plants may be expected to grow large; three or four feet apart in poorer ground, where less growing room is needed.

Between the middle of March and the middle of May planting is in order. The seeds are dropped into the furrows, either by hand or by a machine called a planter, and then lightly covered with about an inch of soil. When the "stand," as the collection of young plants is called, is fairly up, and from six to ten inches high, the thinning out begins. The weaker plants are relentlessly hoed down, the stronger ones are left standing at intervals of twelve or eighteen inches; and before long these are subjected to the process of topping; that is, the uppermost bud of each is clipped off, and the plant, unable to continue its main shoot, sends out numerous side-branches to make up for its deficiency. As all of these side-branches bear blossoms and fruit, the planter's purpose, that of increasing his supply of fibre, is accomplished.

The flowers appear when the plant is from twenty-four to thirty-six inches high, and the bolls open about six weeks after the corolla has fallen.

Though the cotton plant is a biennial or a perennial, it is always treated as an annual; the old plants are removed and new seeds sown each spring. W. B. Dana, in his "Cotton from Seed to

Loom," says: "A cotton seed is something like a bean in its early growth. Within it are two leaves and a tap-root; and after lying in the ground about a week the tap-root strikes down into the earth, while the two leaves open above, growing in a few days from two to three inches high. . . . During the next ten days two more leaves appear, and in the following two weeks from five to six additional ones. . . . When the cotton plant is about twelve inches high it begins to throw out limbs, with leaves about four inches apart, having at every joint a form, or square, or shape — all these names being used for what is really the bud.

"This bud, on its first appearance, is triangular in outline, with three leafy bracts on the outside. . . . The blossom opens after sunrise in the morning, pure white, with three (or four, or five) petals. It begins to close at about two o'clock when a pale red streak may be seen running up each petal, and at sundown it is wholly closed. The next morning, at about sunrise, it is again open, as fresh as ever, but, instead of being white, it is now a beautiful pink. It lasts the day out, but with the setting sun again closes, this time, however, wilting and falling off, leaving at its base a little boll about the size of a small bean."

The boll is filled with young seeds, surrounded by a white pulp-like substance. As the boll matures, the pulp disappears, and the cavity becomes wholly crowded with the densely packed silky hairs, which have grown from the thick coats of the seeds. The pressure of these soft hairs as they expand, finally overcomes the resistance of the seed vessel; the valves part (Fig. 3), and the beautiful white cotton, spreading as it comes in contact with the air, hangs out in snowy "locks" several inches long.

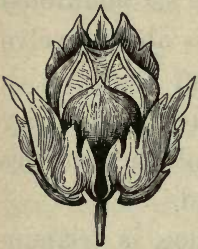

FIG. 3. BOLL OF COTTON (Royle).

The sooner it is picked, now, the better. Exposure to the weather darkens and weakens the fibre. Picking begins in the middle of August, and does not end until the last of September. "The picking is performed," writes Mr. George Emerson, "by male and female hands provided with Osnaburgh bags, hung over the neck and shoulders, into which the cotton is put as fast as picked. These, when full, are emptied into large Osnaburgh sheets, placed at convenient spots; the sheets are carried home in the afternoon. One hand can pick about one hundred pounds per day of seed cotton."

Having been gathered, the cotton is spread out to dry, and when thoroughly dried is ready to be ginned for the market. Whitney's cotton gin consists of a hopper, in which the cotton is confined, and a roller thickly set with circular saws. One side of the hopper has bars, adjusted to admit the edges of the saws, but so close together that when the saw teeth catch the cotton fibres, and pull them out of the hopper, the seeds are held by the bars and remain behind. Stiff brushes then take the cotton from the saws; it is passed between heavy rollers, and comes out in loose, flat sheets. Other gins, different in construction, are also used.

The sheets which come from the gin are rolled in bales, not less than four hundred pounds in weight; the bale cotton is afterward cleaned, carded, drawn into a coarse, loose thread, and then spun into stout or delicate yarns, as the need may be.

The great usefulness of cotton depends, as will be shown by the following extract from Edwin Lancaster's "Remarks on the Natural History of Cotton," on its power of forming a twist. "The cotton fibre is a hair: it does not, however, grow on the surface of the plant. . . . It is not the length or strength of the hair alone which gives to it the power it possesses of forming a thread when twisted. If examined under the microscope, the cotton hair will be found apparently to consist of two delicate, transparent tubes, the one twisted round the other, so as to have the appearance of two pieces of cord wound round each other (Fig. 4). If, however, the hair be examined in its young state, it will be found to be an untwisted, cylindrical tube. It is during its growth that this change takes place. As the seeds and hairs grow, the capsules do not appear to expand with equal rapidity; and, consequently, the hair is exposed to pressure on all sides. The result of this is, that the hair collapses in the middle, leaving a half-formed tube on each side. These uncollapsed portions of the hair give it the 'appearance,' says Bauer, 'of a flat ribbon, with a hem or border at each edge.'

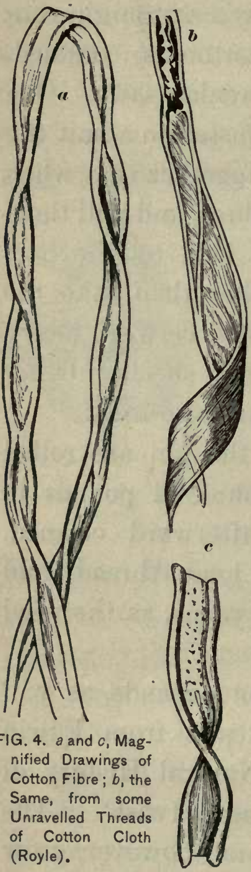

FIG. 4. *a* and *c*, Magnified Drawings of Cotton Fibre; *b*, the Same, from some Unravelled Threads of Cotton Cloth (Royle).

The hair does not, however, grow out straight, but coming in contact with other hairs, and the sides of the capsule or fruit, it becomes twisted; thus acquiring the appearance first described, of two cords twisted together. This twisting is undoubtedly the great fact that makes the cotton hairs of value to man. There are many hairs, such as those of the cotton-grass and the bombax, which are as long, and apparently as strong, as those of the *Gossypium*, but which, failing in this irregularity of their surface, are utterly incapable of being twisted into a thread or yarn."

Of the seeds discarded by the cotton gin, a small proportion are needed for sowing. The remainder were formerly used for enriching the land. They are now, however, turned to better account. The oil which they contain, cotton-seed oil, is valuable for cooking purposes; it forms a good substitute for olive oil, or for lard; it is also excellent for making soap, and for mixing paints. The compact mass which is left, after the oil has been pressed out, is sold as cotton-seed cake, and fed to cows and sheep.

III.

SEED-FOOD.

BY FREDERICK LEROY SARGENT.

In the study of animals we find that as we advance from the lower to the higher forms, there is a wonderful improvement in the way the young are cared for. It is the same with plants, and in those higher forms which produce flowers and seeds the provisions made for the welfare of offspring afford some of the greatest marvels of vegetable life.

One of the most direct and obvious ways in which the well-being of infant plants is promoted is by the store of food that is laid up in the seeds. This enables the sprouting seedling to develop root and leaves before it is thrown entirely upon its own resources; and thus from the start the plantlet can work to advantage.

The amount of this seed-food varies of course very greatly, as we have all sizes of seeds from the tiniest atoms up to such large ones as coco-nuts.[1]

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[1] More commonly but less correctly written "cocoanuts."—See Imperial Dictionary.

But what is more interesting is that the amount of space occupied by the embryo, as compared with the amount of space filled by the seed-food surrounding it, is also very different in different seeds. In some cases, as for example in the coco-nut, the nutmeg, and the date seed, the embryo is a mere speck embedded in copious seed-food, much as in a hen's egg the germ of the chick is surrounded by the yolk and albumen. This resemblance suggested to botanists the name albumen as a good one to use for the seed-food which accompanies an embryo. In other seeds such as those of maize, morning-glory, and the castor-oil plant, we find a medium-sized embryo and a moderate amount of albumen; such might be compared to an egg in which the chick had become partly developed at the expense of the surrounding food. Finally there are many seeds which like peanuts, almonds, and chestnuts, are destitute of albumen; but these have the space within the shell filled by a well-developed embryo, more or less gorged with food, and here we have something to remind us of an egg just ready to hatch. In every case the plantlet gets all the food sooner or later, the only difference being that some have to absorb more or less at the time of germination, while with others the entire food-supply is deposited within the embryo during the formation of the seed.

In the various kinds of eggs there is scarcely any difference in the nature of the food-supply. Chemically considered, the contents of a hen's egg is practically the same as that of other eggs. It is not so, however, with the food-supply of seeds, for very various substances are made use of by different plants. Among these the most important are starch, oils, and albuminoids.

Starch forms about a third of the bulk of beans and peas ; from half to two-thirds of wheat, oats, rye, and barley ; and over four-fifths of maize and rice. It is very much like sugar in its chemical composition, and has about the same value as a food.

Oil occurs in small quantities along with the starch in the seeds just mentioned, but in many cases it entirely replaces the starch, and forms the principal part of the seed-food. Peanuts and cotton seeds, for example, are very rich in an oil which is extensively used as a substitute for that obtained from olives. Walnut oil is put to the same use. Flaxseeds afford the linseed oil so valuable as a medium for mixing paints. The albumen of the coco-nut when boiled and pressed yields

Louise L. Quackenbush

two fatty substances: one, called stearine, is solid at ordinary temperatures, and is used in the manufacture of candles; the other, being liquid, is burned in lamps, or when fresh is used in cookery. Some of our most valued nuts, such as the butternut, hickory, pecan-nut, Brazil-nut, pistachio-nut and almond, owe their rich flavor to the abundant oil they contain.

In point of nutritive value the albuminoids form by far the most important constituents of seed-food, for in chemical composition they are very similar to egg-albumen. No seeds are entirely destitute of albuminoids, but as a rule the quantity is not very large. In the cereals the proportion ranges from seven and one-half per cent in rice to nineteen per cent or more in wheat. Peas and beans are the most nutritious seeds that we commonly use, as about one quarter of their bulk is albuminoid material. The value of wheat is greatly enhanced by the fact that its albuminoid food consists almost wholly of gluten. This substance it is which imparts to macaroni its peculiar firmness and elasticity, and which gives to wheaten dough that tenacity upon which the making of raised bread depends.

Of all the sorts of food which plants lay by in special organs as a reserve for the future, seed-food is the most compact, as it is the freest from water; for the same reason it is least liable to change with long keeping, and from the larger proportion of albuminoids contained it is the most nutritious. This has led man from the earliest times to use seeds as the chief source of their vegetable food; many of the very kinds whose seed-food we appropriate nourished men ages before the pyramids were built. The evidences which have come down to us of their earliest use are fragmentary, but they clearly show that these productions must have been of the utmost value to the men of those days, and they are well calculated to impress the mind with a sense of the importance to human life of plants which have afforded the best food from prehistoric times to the present day.

We learn from De Candolle that some of the most ancient Egyptian monuments, older than the Hebrew Scriptures, show the cultivation of wheat already established, and when the Egyptians or Greeks speak of its origin, they attribute it to the mythical personages Isis, Ceres, or Triptolemus. One interesting discovery of the Egyptologists was the finding of a grain of wheat embedded in a brick of the pyramid of Dashour, to which the date 3359 B.C. has been assigned. There is also evidence of the cultivation of barley, millet, and a kind of lupin, in Egypt during prehistoric times. Herodotus tells us that the lentil was largely used by the ancient Egyptians, but because they considered it common and coarse it found no place upon their monuments. The red pottage for which Esau sold his birthright was made of lentils, the color being due in all probability to the seeds having been hulled, thus exposing the pale-red kernels. It is still the practice in that region to cook lentils in this way.

The occurrence of Sanskrit names for the lentil, chick-pea, barley, millet, walnut, sesame, and castor-oil plant, indicate a very ancient use in India.

It is recorded that the Chinese Emperor Chinnong, who lived about 2700 B.C. instituted the annual ceremony of sowing seeds of the five most important plants of the Empire, as a token of appreciation and gratitude for these gifts of Heaven. The plants chosen were rice, wheat, sorghum, a sort of millet, and a bean-like plant known as soy, from which substances similar to butter and cheese are largely extracted. No less a personage than a prince of the royal blood can take part in the ceremony, and the planting of the rice seeds must be performed by the emperor himself. When we realize that rice gives food to more human beings than any other plant, it is not difficult for us to sympathize with the feeling that prompts such special consideration for this invaluable grain.

At a time probably anterior to the Trojan War, before the dawn of European history, there lived in the region of Switzerland a half-savage people, of whose existence we know from remains of their dwellings which have been discovered in the lakes. Along with primitive implements of stone or bronze have been found the seeds of wheat, two kinds of barley, oats, lentils, and our common garden pea.

Early Grecian coins and passages from the ancient writers show that the lentil, chick-pea, garden pea, millet, and wheat were well known to the Greeks. Barley was highly prized by them as a strong food for athletes in training, and they often represented the goddess Ceres with ears of this grain plaited in her hair. A six-rowed variety of barley is pictured upon medals of the Italian town Metapontis, which date from about 600 B.C.

Some of our most valued seed plants are products of our own country, and were found in extensive cultivation by Columbus and his followers. Cacao[1] was largely used, and so highly prized that the seeds served as money. The peanut, now widely cultivated in many parts of the world, is in all probability a native of tropical America, and the fact that seeds of the plant have been found in ancient Peruvian tombs at Ancon, gives evidence of use in quite early times. In these same tombs have been found seeds of the Lima-bean and our common pole-bean. By far the most important of American vegetable products is the maize or Indian corn, and we have abundant proof of its very ancient and widespread cultivation. Aboriginal burial mounds, the tombs of the Incas, and the catacombs of Peru have been found to contain ears or grains of maize. Just as the ancient Greeks offered the first fruits of their grain harvest to the goddess Ceres, so the Aztecs brought to their goddess *Cinteutl* the first ears from their maize fields. Although this old Mexican custom may not antedate the Christian era, still the development of such a ceremony must have been preceded by a long period of widespread use.

With many plants provision is made for defending the seed-food against the depredations of seed-eating animals; but strange to say, some of the most effective of these means of defence constitute the very attractions which lead to our using the seeds. For example, it is probable that no wild animal would think of eating mustard seeds — at least a second time. Nutmegs are quite as well protected by the aromatic oil which many of us prize so highly, but which is probably distasteful to animals, and if taken in quantity is poisonous. To a certain extent the same is true of coffee and cacao seeds, both of which are decidedly unpalatable in the raw state.

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[1] More commonly but less correctly written "cocoa." — See Imperial Dictionary.

Certain seeds containing the most virulent poisons afford drugs which are often of great value in medicine. *Nux vomica*, for example, yields the important drug strychnine. The seeds of larkspur, foxglove, lobelia, henbane, sabadilla, colchicum, stramonium, croton and bitter-almond are each rich in some powerful medicinal principle.

Perhaps the most curious expedient resorted to for protection is hardening the seed-food to an extent which will defy the best of teeth. A good example of this is the ivory-nut, which is largely imported from South America, and its albumen used as a substitute for animal ivory in the manufacture of buttons, knobs, toys, and other small articles. The same hardening of albumen occurs in the coquilla-nuts of Brazil, and causes them to be in much demand for making door knobs, umbrella handles, and such articles of turnery.

Besides the substances we have mentioned as being contained in seeds there are others, such as alcohol and certain sugars which are obtained from seeds by inducing chemical changes in their contents. To consider these artificial products would lead us too far from our subject, for a proper understanding of the processes of manufacture would carry us deep into chemistry, and what is more, the substances so produced are not seed-food.

IV.

MOVEMENTS OF SEEDLINGS.

THE tips of all young growing parts of the higher plants continually revolve, bowing successively towards every point of the compass. Darwin calls this movement *circumnutation.* In the introduction to his book,[1] "The Power of Move-

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[1] "The Power of Movement in Plants" was published in 1880. Darwin had previously published, in 1875, an essay on "Climbing Plants," in which he had shown that the young tips of twining stems, tendrils, leaf-stalks, etc., continually revolve, and that this movement is the immediate cause of their twining. The later work extends this conception to the tips of all young growing parts of plants. In his autobiography, Darwin says, "In accordance with the principle of evolution it was impossible to account for climbing plants having been developed in so many widely different groups, unless all plants possess some slight power of movement of an analogous kind. This I proved to be the case, and I was further led to a rather wide generalization, viz., that the great and important classes of movements excited by light, the attraction of gravity, etc., are all modified forms of the fundamental movement of circumnutation. It has always pleased me to exalt plants in the scale of organized beings; and I therefore felt an especial pleasure in showing how many and what admirably well adapted movements the tip of a root possesses."

The conclusions of this book have not been generally accepted, and have met with much criticism, especially in Germany. Francis Darwin says ("Life and Letters of Charles Darwin," II. p. 502), "The central idea of the book is, that the movements of plants in relation to light, gravitation, etc., are modifications of a spontaneous tendency to revolve ment in Plants," he says,[1] "The chief object of the present work is to describe and connect together several large classes of movement, common to almost all plants. The most widely prevalent movement is essentially of the same nature as that of the stem of a climbing plant, which bends successively to all points of the compass, so that the tip revolves. This movement has been called by Sachs 'revolving nutation,' but we have found it much more convenient to use the terms *circumnutation* and *circumnutate.* As we shall have to say much about this movement, it will be useful here briefly to describe its nature. If we observe a circumnutating stem, which happens at the time to be bent, we will say towards the north, it will be found gradually to bend more and more easterly, until it faces the east; and so onwards to the south, then to the west, and back again to the north. If the movement had been quite regular, the apex would

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or circumnutate, which is widely inherent in the growing parts of plants. This conception has not been generally adopted, and has not taken a place among the canons of orthodox physiology."

Nevertheless the book is one of exceeding interest. One critic has said, "No one can doubt the importance of what Mr. Darwin has done, in showing that, for the future, the phenomena of plant movement can, and indeed must be, studied from a single point of view."

[1] "The Power of Movement in Plants." By Charles Darwin and Francis Darwin. New York: D. Appleton & Co. 1888. p. 1. The references in this chapter are all to this work.

have described a circle, or rather, as the stem is always growing upwards, a circular spiral. But it generally describes irregular elliptical or oval figures; for the apex, after pointing in any one direction, commonly moves back to the opposite side, not, however, returning along the same line. . . .

"In the course of the present volume it will be shown that apparently every growing part of every plant is continually circumnutating, though often on a small scale. Even the stems of seedlings before they have broken through the ground, as well as their buried radicles, circumnutate as far as the pressure of the surrounding earth permits. In this universally present movement we have the basis or groundwork of the acquirement, according to the requirements of the plant, of the most diversified movements. Thus, the great sweeps made by the stems of twining plants, and by the tendrils of other climbers, result from a mere increase in the amplitude of the ordinary movement of circumnutation."[1]

After minute descriptions of many experiments on the movements of radicles and cotyledons of seedlings, he says: —

"In all the germinating seeds observed by us, the first change is the protrusion of the radicle, which immediately bends downwards and endeavors to penetrate the ground. In order to effect this, it is almost necessary that the seed should be pressed down so as to offer some resistance, unless indeed the soil is extremely loose; for otherwise the seed is lifted up, instead of the radicle penetrating the surface. But seeds often get covered by earth thrown up by burrowing quadrupeds or scratching birds, by the castings of earthworms, by heaps of excrement, the decaying branches of trees, etc., and will thus be pressed down; and they must often fall into cracks when the ground is dry, or into holes. Even with seeds lying on the bare surface, the first developed root-hairs, by becoming attached to stones or other objects on the surface, are able to hold down the upper part of the radicle, whilst the tip penetrates the ground. . ." [1] This is well seen in the germination of Clover.

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[1] p. 3.

"The tip of the radicle, as soon as it protrudes from the seed-coats, begins to circumnutate, and the whole growing part continues to do so, probably for as long as growth continues. . . ."

Then comes into play the action of gravitation, which causes the root to bend downwards towards the centre of the earth. This bending is called *geotropism*, from two Greek words meaning, "the earth," and "to turn."

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[1] p. 69.

"Sensitiveness to gravitation," says Darwin, speaking of the radicle of the seedling, "resides in the tip; and it is the tip which transmits some influence to the adjoining parts, causing them to bend. As soon as the tip, protected by the root-cap, reaches the ground, it penetrates the surface, if this be soft or friable, and the act of penetration is apparently aided by the rocking or circumnutating movement of the whole end of the radicle.[1]

"After the tip has penetrated the ground to a little depth, the increasing thickness of the radicle, together with the root-hairs, hold it securely in its place; and now the force exerted by the longitudinal growth of the radicle drives the tip deeper into the ground. This force, combined with that due to transverse growth, gives to the radicle the power of a wedge. Even a growing root of moderate size, such as that of a seedling bean, can displace a weight of some pounds."[2]

The radicle is constantly growing in length, and at the same time in thickness. Darwin says,[3]

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[1] p. 548. [2] p. 549. [3] p. 77.

"The growing part, therefore, does not act like a nail when hammered into a board, but more like a wedge of wood, which whilst slowly driven into a crevice, continually expands at the same time by the absorption of water; and a wedge thus acting will split even a mass of rock" (Fig. 5).[1]

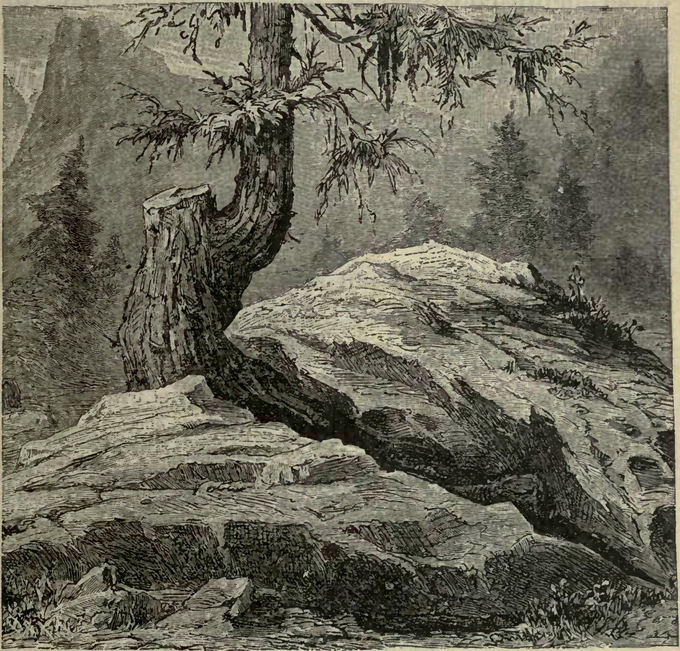

FIG. 5. SPLITTING OF A ROCK BY THE GROWTH OF THE ROOT OF A LARCH.
("Pflanzenleben.")

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[1] "The great force exerted by the increase in size of the stems and roots of woody plants is sometimes demonstrated in an extraordinary

Darwin tried many experiments to ascertain how the movements of the radicle were affected by contact with external objects. Some of these experiments consisted in affixing, by shellac, or gum, small bits of card to one side of the tip of the radicle. The whole growing part of the radicle bent away from the side bearing the card, or, when card was placed on one side and paper on the other, the radicle bent towards the thinner paper. He also found that radicles bent toward moisture and away from light. "It is not probable that the tip when buried in compact earth can actually circumnutate, and thus aid its downward passage, but the circumnutating movement will facilitate the tip entering any lateral or oblique fissure in the earth, or a burrow made by an earthworm or larva; and it is certain that roots often run down the old burrows of worms. The tip, however, in endeavoring to circumnutate, will continually press against the earth on all sides, and this can hardly fail to be of the highest

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manner by the development of seedlings in crevices. Thus, at the Marien Cemetery, in Hanover, Germany, the base of a tree has dislodged the stones of a strongly built tomb. One of the stones, which measures 23 by 28 by 56 inches has been lifted upon one side to the height of five inches. The tree measures just above its base from ten to fourteen inches in diameter." "Physiological Botany." By George Lincoln Goodale. Ivison, Blakeman, Taylor & Co.: New York and Chicago. p. 395, note 3.

importance to the plant; for we have seen that when little bits of card-like paper, and of very thin paper, were cemented on opposite sides of the tip, the whole growing part of the radicle was excited to bend away from the side bearing the card, or more resisting substance, towards the side bearing the thin paper.[1] We may therefore feel almost sure that when the tip encounters a stone or other obstacle in the ground, or even earth more compact on one side than the other, the root will bend away as much as it can from the obstacle or the more resisting earth, and will thus follow with unerring skill a line of least resistance . . ."[2] (Fig. 6).

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[1] "The accompanying figures of four germinating seeds (Fig. 6) show, firstly, a radicle (A), the apex of which has become so much bent away from the attached square as to form a hook; secondly (B), a hook converted through the continued irritation of the card, aided perhaps by geotropism, into an almost complete circle or loop. The tip in the act of forming a loop generally rubs against the upper part of the radicle, and pushes off the attached square; the loop then contracts or closes, but never disappears, and the apex afterwards grows vertically downwards, being no longer irritated by any attached object. This frequently occurred, and is represented at (C). . . . In another case, shown at (D), the apex in making a second turn or spire, passed through the first loop, which was at first widely open, and in doing so knocked off the card; it then grew perpendicularly downwards, and thus tied itself into a knot, which soon became tight." "Power of Movement in Plants," p. 178. The conclusions drawn from these experiments are not accepted by many students, and the experiments themselves are criticised, as containing sources of error.

[2] p. 549.

"After a radicle has been deflected by some obstacle, geotropism directs the tip again to grow perpendicularly downwards; but geotropism is a

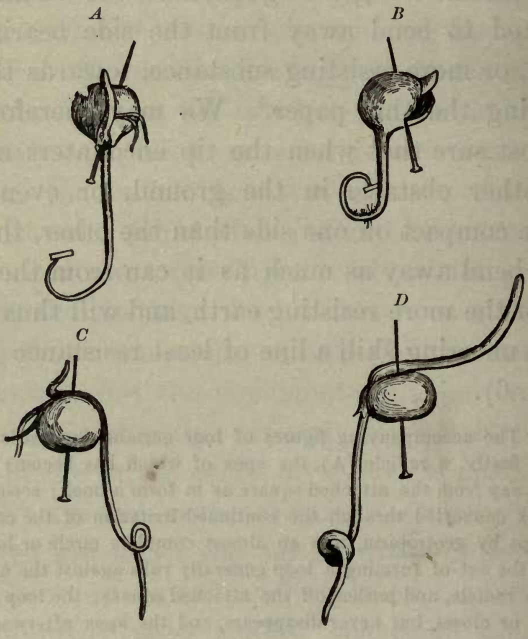

FIG. 6. ZEA MAYS. Radicles excited to bend away from the Little Squares of Card attached to One Side of their Tips (Darwin). See Note.

feeble power, and here, as Sachs has shown, another interesting adaptive movement comes into play; for radicles at a distance of a few millimetres from the tip are sensitive to prolonged contact in such a manner that they bend towards the touching object, instead of from it, as occurs when an object touches one side of the tip. Moreover, the curvature thus caused is abrupt, the pressed part alone bending. Even slight pressure suffices, such as a bit of card cemented to one side. Therefore a radicle, as it passes over the edge of any obstacle in the ground, will, through the action of geotropism, press against it, and this pressure will cause the radicle to endeavor to bend abruptly over the edge. It will thus recover as quickly as possible its normal downward course.

" Radicles are also sensitive to air which contains more moisture on one side than the other, and they bend towards its source. It is therefore probable that they are in like manner sensitive to dampness in the soil. It was ascertained in several cases that this sensitiveness resides in the tip, which transmits an influence causing the adjoining upper part to bend in opposition to geotropism towards the moist object. We may therefore infer that roots will be deflected from their downward course toward any source of moisture in the soil.

" Again, most or all radicles are slightly sensitive to light, and, according to Wiesner, generally bend a little from it. Whether this can be of any service to them is very doubtful, but with seeds germinating on the surface it will slightly aid geotropism in directing the radicles to the ground. We ascertained in one instance that such sensitiveness resided in the tip and caused the adjoining parts to bend from the light. . . ."[1]

"We believe that there is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. If the tip be lightly pressed or burned or cut, it transmits an influence to the upper adjoining part, causing it to bend away from the affected side; and, what is more surprising, the tip can distinguish between a slightly harder and softer object, by which it is simultaneously pressed on opposite sides. If, however, the radicle is pressed by a similar object a little above the tip, the pressed part does not transmit any influence to the more distant parts, but bends abruptly towards the object. If the tip perceives the air to be moister on one side than on the other, it likewise transmits the influence to the upper adjoining part, which bends towards the source of moisture. When the tip is excited by light (though in the case of radicles this was ascertained in only a single instance) the adjoining part bends from the light; but when excited by gravitation the same part bends towards the centre of gravity. In almost every case we can clearly perceive the final purpose or advantage of the several movements. Two, or perhaps more, of the exciting causes often act simultaneously on the tip, and one conquers the other, no doubt in accordance with its importance for the life of the plant. The course pursued by the radicle in penetrating the ground must be determined by the tip; hence it has acquired such diverse kinds of sensitiveness. It is hardly an exaggeration to say that the tip of the radicle, thus endowed, and having the power to direct the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements."[1]

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[1] pp. 551, 552.

In seedlings, such as the Bean (Fig. 8), and Squash (Fig. 9), which lift their cotyledons above the ground, the stem below the cotyledons, called by Darwin the *hypocotyl*, is the first to break out from the seed-coats after the protrusion of the radicle. In seedlings, such as the Pea, where the

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[1] p. 572. This is considered an extravagant assumption by Sachs and others.

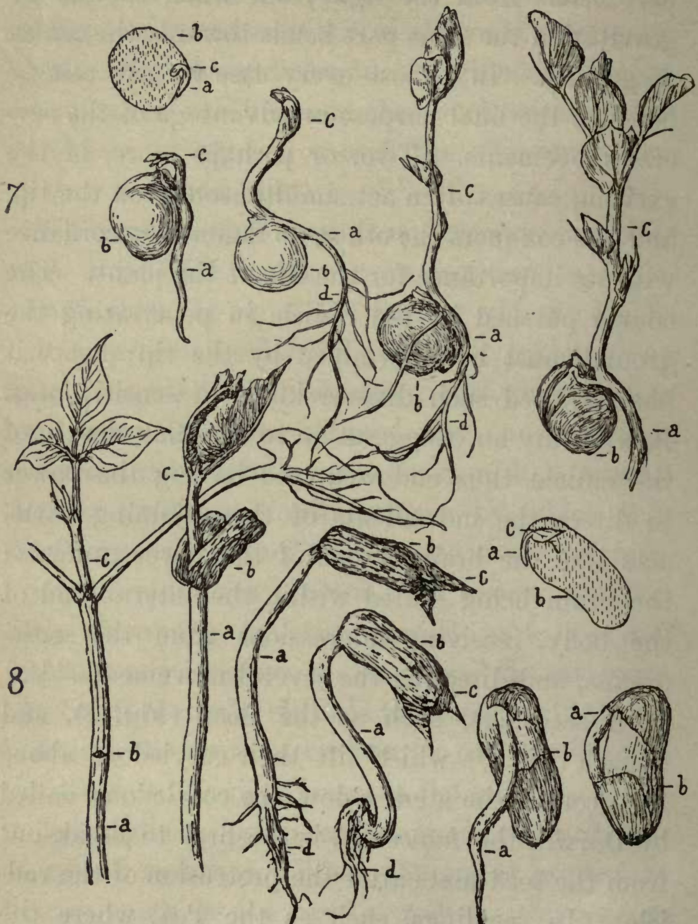
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FIG. 7. GERMINATION OF PEA. FIG. 8. GERMINATION OF BEAN.

cotyledons remain buried (Fig. 7), the stem above cotyledons, the epicotyl, breaks forth. These organs are generally arched at first; this form probably saves the tender, growing apex from being rubbed.

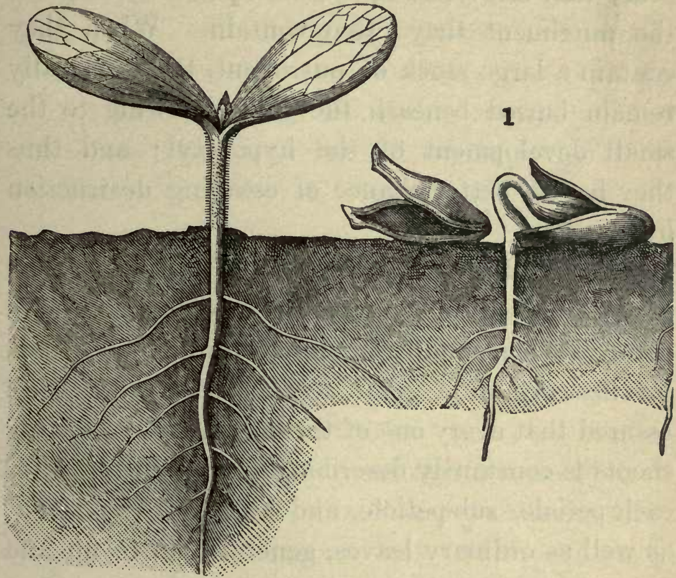

FIG. 9. GERMINATION OF SQUASH (Cucurbita Pepo).

"As the arch grows upwards, the cotyledons are dragged out of the ground. The seed-coats are either left behind buried, or are retained for a time, still enclosing the cotyledons. These are afterwards cast off merely by the swelling of the cotyledons. . . . The cotyledons can now assume the function of leaves and decompose carbonic acid; they also yield up to other parts of the plant the nutriment they often contain. When they contain a large stock of nutriment, they generally remain buried beneath the ground, owing to the small development of the hypocotyl; and thus they have a better chance of escaping destruction by animals. . . ."[1]

"Our seedling now throws up a stem bearing leaves, and often branches, all of which whilst young are continually circumnutating. If we look, for instance, at a great acacia tree, we may feel assured that every one of the innumerable growing shoots is constantly describing small ellipses; as is each petiole, sub-petiole, and leaflet. The latter, as well as ordinary leaves, generally move up and down in nearly the same vertical plane, so that they describe very narrow ellipses. The flower-peduncles are likewise continually circumnutating. If we could look beneath the ground, and our eyes had the power of a microscope, we should see the tip of each rootlet endeavoring to sweep small ellipses or circles as far as the pressure of the surrounding earth permitted. All this astonishing amount of movement has been going on year after year since the time when, as a seedling, the tree first emerged from the ground."[1]

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[1] p. 556.

[1] p. 558.

V.

THE BIRTH OF PICCIOLA.[1]

One day, at the usual hour, De Charney was walking in the courtyard of his prison, his eyes cast down, his arms crossed behind him. He was pacing slowly step by step, as if thus he could enlarge the narrow space permitted to him.

Spring was approaching; he breathed a sweeter air, and to be free, master of the earth and of space, seemed to him an object of desire.

He counted one by one the stones of the little courtyard, perhaps to verify former calculations, for it was not the first time that he had numbered them, when he saw at his feet a small mound of earth, slightly cleft at the summit, thrown up between two paving-stones. He stooped, and his heart beat quickly, without his knowing why. Everything is an object of hope or fear to the captive; for the most insignificant events he seeks some important cause which may bring about his deliverance. Perhaps this slight disturbance at the surface is produced by some great work below. There may be passages beneath the earth which will open and admit him to the fields and mountains. Perhaps his former friends and confederates are digging a mine in order to reach him and bring him back to life and liberty.

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[1] Translated from the French of Joseph Xavier Saintine. "Picciola," Chap. III. Picciola (signifying "dear little one") is the name given by Count de Charney, a political prisoner of Napoleon in the fortress of Fenestrella, to a plant which had sown itself in the courtyard of his prison.

He listens attentively and thinks he hears a dull, prolonged sound from the interior of the fortress; he raises his head, and the breeze brings him the rapid clang of the tocsin. The rolling of drums is repeated like a signal of war along the ramparts. He trembles and brushes the sweat convulsively from his forehead. Will he soon be free? Has France changed her master?

The dream vanishes; reflection destroys the illusion. Confederates he has no longer, and friends he never possessed. He listens again. The same noises strike his ear, but they bring far other thoughts. This clang of the tocsin, this rolling of the drum, are only the accustomed striking of a clock, and the usual call which summons the soldiers of the citadel to their daily drill.

De Charney smiled bitterly and pitied himself to think that a tiny animal, a mole that had lost its way, a field-mouse scratching up the earth beneath his feet, had made him believe for an instant in the fidelity of men and the overthrow of a great empire.

He wished to satisfy himself, however, and bending down, he pushed away the earth on either side of the cleft hillock. He saw then with astonishment that his foolish emotion had been caused not even by a sentient being, armed with claws and teeth, but by a feeble plant, hardly able to germinate, pale and languishing. Profoundly humiliated, he rose and was about to crush it under his heel, when a fresh breeze, laden with the odor of honeysuckle and of syringa, blew across his face as if to ask mercy for the poor plant, which perhaps some day would also be able to offer him perfumes.

An idea struck him which arrested his movement of disgust.

How had this tender herb, so fragile that it might be broken at a touch, been able to pierce the dry, sun-hardened earth, trodden by his footsteps, and almost cemented to the granite flags. He bent again and examined the plant with more attention.

He saw at its upper extremity a sort of double fleshy valve, which, embracing its first leaves, preserved them from the attacks of enemies, and gave them the means of breaking through the hard crust of earth to seek the air and the sun.

"Ah," he said, "there is the whole secret. Nature has given it this strength, like the little chickens, which, before they are hatched are already armed with a beak strong enough to break the shell in which they are enclosed. Poor prisoner! at least you possess in your captivity instruments which will aid you to become free."

He looked at the plant and no longer thought of destroying it.

The next day, in his usual promenade, walking with long strides and absorbed in his own thoughts, he almost stepped upon it and stopped short. Surprised by the interest which his new acquaintance inspired in him, he noted its progress.

The plant had grown, and under the rays of the sun had nearly lost the sickly pallor of the previous day. He reflected on the power of this weak, blanched stem to absorb the light, to nourish itself, to strengthen itself, and to borrow from the prism the colors which it needed, colors foreordained for every one of its parts.

Its leaves, he thought, will doubtless be tinted with a different shade from its stem, and of what color will the flowers be? Yellow, blue, red? Why, since they are fed by the same juice as the stem and leaves, do they not clothe themselves in the same livery? How can they find azure and scarlet where the others find only a bright or dark green? It will be so, however; for, in spite of the disorder and confusion of the world, matter follows its fixed, though blind march. "Very blind," he repeated. "To prove it I should only need to see that the two fleshy lobes which have aided the plant to leave the earth, but are now useless to its life, are still nourished by its substance, and, hanging down, weary it with their weight. Of what use are they now?" As he spoke, night was approaching, — a wintry spring night. The two lobes rose slowly, under his very eyes, and as if wishing to justify themselves against his blame, approached each other and enclosed in their bosom the tender, fragile leaves, which the sun was leaving, and which, thus sheltered and warmed, slept beneath the protecting wings that the plant folded over them.[1]

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[1] This is perhaps the first allusion to the sleep of cotyledons. "Picciola" was published in 1856. Darwin, in "The Power of Movements in Plants," published in 1880, investigates the subject, and concludes thus: "Reflecting on these facts, our conclusion seems justified, that the nyctitropic movements of cotyledons, by which the blade is made to

The philosopher understood still better this mute but decisive answer, because the outer surfaces of the vegetable bivalve had been attacked and bitten the night before by little snails, whose silvery traces were still visible.

This strange discussion, thoughts on one side and action on the other, between the man and the plant, could not rest there. De Charney was too familiar with metaphysics to be vanquished so readily by a good argument.

"Very well," he replied; "here, as elsewhere, a happy combination of circumstances has favored this weak being. To be armed with a lever to raise the soil, and a buckler to protect its tender head, is a twofold condition of its existence. If this had not been fulfilled, the plant would have perished in its germ, like myriads of others of its kind, that Nature has doubtless created imperfect, unfinished, unable to live and grow. How can one guess how many false and impotent combinations she has tried before bearing a single being fitted to live? For thousands of centuries matter has

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stand either vertically, or almost vertically, upwards or downwards at night, has been acquired, at least in most cases, for a special purpose: nor can we doubt that this purpose is the protection of the upper surface of the blade, and perhaps of the central bud or plumule, from radiation at night."

been torn by alternate attraction and repulsion. Is it then surprising that chance has sometimes hit the mark? This covering may protect the first leaves, — I grant it; but will it increase, will it shelter the other leaves against the cold and the attacks of insects? No. The next spring, when another foliage will be born, fragile as this, will it be here to protect that? No. Nothing here has been foreseen, nothing is the fruit of intelligent thought, but only of a lucky chance."

Ah, Count de Charney, nature holds more than one answer to refute your arguments. Wait, and see in this weak and solitary plant, brought to you in the dulness of your prison, a beneficent thought of Providence rather than a stroke of chance. These excrescences, in which you yourself have divined a lever and a shield, have already rendered other services to this feeble plant. After having served it through the winter as a covering in the cold soil, when the right time arrived they lent it their nourishing breasts, they fed the simple germ when it had neither roots to draw the moisture from the earth, nor leaves to breathe the air and the sun. You are right, Count de Charney; these protecting wings which now cover the young plant so maternally will not develop with her; they will fall, but after having finished their task and when their charge has acquired the strength to do without them. Do not trouble yourself about the future. Nature watches over this plant, as over her sisters, and while the northern winds bring the snow and hail from the Alps, the new leaves, still in the bud, will find there a sure refuge, an asylum made especially for them, closed from the air, covered with gum and resin, that expands according to their needs, and opens only at the right time, under a favorable sky. They will issue clad in warm furs, silky garments of down that will defend them from the late frosts and atmospheric caprices. Has ever a mother watched more carefully the welfare of her children ?

The philosopher had followed attentively the progress and transformations of the plant. Again and again he had argued with her, and for every argument she had her answer.

" Of what use are these stiff hairs that clothe your stem ? " he asked her.

And the next day she showed them to him covered with a light frost, which, held thus at a distance, had not been able to freeze the tender bark.

" Of what use in fine weather will be your warm covering of wool and down ? "

The fine weather came, and the plant took off her winter mantle to put on her spring garment of green, and her new branches were without these silky coverings, henceforth useless.

"But if the storm rage, the wind will break you, and the hail will tear your leaves, too tender to resist."

The wind blew, and the young plant, too weak to resist, bent to the earth, defending itself by yielding. The hail came, and by a new manœuvre, the leaves, ranging themselves along the stem and pressing one against the other for mutual protection, offered their solid ribs to the weight of the missiles. Union gave them strength, and this time, as before, the plant came out of the combat, not without some light wounds, but living, strong, and ready to expand under the rays of the sun, which was already healing its injuries.

"Is chance, then, intelligent?" cried De Charney. "Must we spiritualize matter or materialize spirit?" And he did not cease to interrogate his mute interlocutor. He loved to see her grow, to follow her in her gradual changes.

One day, after he had long contemplated her, he fell into a reverie by her side, and his thoughts had an unusual sweetness. Walking up and down the court, he felt calm and happy in them. Then, raising his head, he saw at the grated window the flycatcher, who seemed to be observing him. He blushed at first as if the other had guessed his thoughts, and then smiled, for he despised his neighbor no longer. Had he the right to do so? Was not his spirit, also, absorbed in the study of one of the lowest works of nature?

"Who knows," he cried to himself, "if this Italian has not found as many wonders in a fly as I have discovered in my plant?"

Entering his cell, the first thing which caught his eye was this fatalistic sentence, written by himself upon the wall two months before: *Chance is blind and is the sole author of creation.*

He took a bit of charcoal and wrote beneath the words, *perhaps.*

VI.

ROOT AND CROWN.[1]

THE GUIDING OF RAINWATER TO THE ROOTLETS.

Any one who has been overtaken by a sudden storm, and has taken refuge under the branches of a tree, will remember that the leafy roof above him afforded him shelter for a time, and that the ground under the tree did not become wet. A part of the rain, to be sure, runs down the tree trunk, and in many kinds of trees, as, for instance, the Yew and the Plane, this quantity is not insignificant; but in most trees, the rainwater that thus reaches the earth quickly disappears, and is hardly to be compared with the amount that pours from the circumference of the leafy crown of the tree. This effect is brought about by the position of the surfaces of the leaves. In almost all our deciduous trees, in the Linden and Birch, Pear and Apple, Plane and Maple, Ash and Horse-chestnut, Poplar and Alder, the leaves of the crown slope outwards and lap over each other, so that the rain which strikes on any one of the upper leaves of the tree runs down to the apex of the leaf, where it collects in the form of a drop, and falls on the shelving surface of a leaf below. There it unites with freshly fallen water, and so descends from step to step, drawing ever nearer to the edge of the tree, till it finally shows itself in a number of little cascades on every side.

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[1] Freely translated from the German of Dr. A. Kerner von Marilaun. "Pflanzenleben." Leipzig, 1888. Vol. I. p. 85.

From the lower, outer leaves of the whole crown the water falls on the earth, and the dry ground under the tree is enclosed after every rain by a zone of thoroughly wet soil. If we dig in these wet places, we find that the young roots with their absorbing fibrils have penetrated just as far as this wet zone. In young trees, where the rootlets are near the tree trunk, the crown is less spreading and the wet zone is of correspondingly small circumference. But as the reach of the drip widens, the roots, seeking moisture, also extend, and roots and leaves actually keep step in their outward growth. It seems to me probable that the gardener's custom of pruning the branches and roots of the trees which he transplants is for the purpose of bringing them into accordance with this law. Practically, the gardener or farmer always observes the rule that the branches of the root and the branches of the crown shall be equally shortened, so that the forming roots shall be directly under the drip of the forming crown.

There is also a similar way of carrying off the water to be observed in the Evergreens. Let us look at the common Pine.[1] The branches start nearly at right angles with the trunk, run out horizontally for some distance, and then curve upwards in the form of a bow. The needles near the end of every branch point upwards, while those a little further from the end, where the branch is almost horizontal, are directed obliquely downwards and outwards. The raindrops which strike the upraised needles run down along them to the bark of the branch, and thence to other needles with their points directed downwards and outwards. On the ends of these needles great drops are gradually formed, which finally drop off and fall on the upraised needles of a lower branch. Guided in this manner, the rainwater is brought ever lower and lower, and at the same time towards the exterior of the tree.

So it is with the Larch. The raindrops which fall on the bushy young sprouts collect and come gradually to the long, pendent shoots of the lower branches, where great drops are always to be seen on the ends pointed to the ground. These drops finally make a stream which falls on the earth. The long, pendent shoots of the Larch droop from the outmost point of every branch, and the tree is in the form of a pyramid, so that nearly all the water that falls upon the tree reaches the long shoots that hang down from the lowest, most extended branches. Although the Larch, with its tender needles, does not seem as if it would afford shelter from the rain, nevertheless, the ground under it remains dry, and most of the rainwater falling on it is brought to the circumference of the tree. In fact, it is one of those trees where very little water runs down the main stem; almost all the rain which reaches it is guided to the rootlets at a certain distance from the trunk.

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[1] The common Pine in Germany is the Scotch Pine (*Pinus sylvestris*).

Many shrubs and perennial herbs also guide the rainwater to that part of the soil in which the rootlets are embedded, or, to be more precise, the roots, with their delicate fibrils, grow in the direction where the drip from the leaves moistens the ground. Some members of the *Arum* family are especially striking in this respect. Fig. 10 represents a Caladium. If one of these plants, which has been cultivated in open ground, be dug up, the ends of the roots, which run out horizontally from the stubby rootstock, will be found embedded directly under the points of the large leaves.

It must not remain unnoticed that the petioles of leaves which lead the rainwater centrifugally, as the leaves of Horse-chestnut and Maple, of shrubs like the Lilac, and of climbing plants like the Tropæolum,[1] are not channelled on the upper side, but are round and smooth. If a sloping leaf shows a system of channels for the water, these channels run along the veins and end at the apex of the leaves, or at the points of the lobes. There the water collects in the form of drops, and must fall on the leaves which make the succeeding lower and outer steps.

In striking contrast to these plants, with leaves sloping outwards and roots spreading horizontally, are those with bulbs or short rootstocks and descending rootlets. This contrast in the growth of the root is shown in Fig. 10, 1 and 2. Above the ground it is foretold by the form and position of the leaves on which the rainwater strikes. In all these plants the leaf surfaces slope towards the axis.

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[1] When several examples of plants, illustrating a single point, are given, the liberty has been taken of choosing those only which are well-known in America. — Ed.

They are also concave on their upper side, and often show a system of channels which guides the water to the stem, and thence to the tap-root and short absorbing rootlets. The leaves of bulbous plants, like those of the Hyacinth and Tulip, all slope inward and are concave on the upper side, and often excavated into deep channels. Through these channels the rainwater runs, and so reaches that part of the earth where the bulb with its

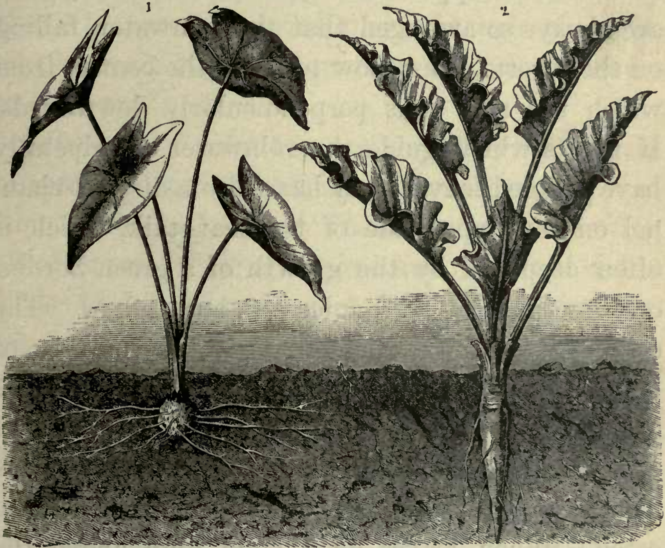

FIG. 10. CENTRIFUGAL AND CENTRIPETAL CONDUCTING OF WATER.
1. In a Caladium. 2. In a Rhubarb Plant. ("Pflanzenleben.")

mass of rootlets is embedded. In plants with rootstocks, if the leaves are in a rosette and the rosette lies on the ground, as with the Dandelion, Plantain, etc., a channel or several main channels are to be found on the upper side of the leaf, and the leaves are always so arranged that the rainwater, falling on the rosette, must flow towards the centre, from which the root runs perpendicularly downwards. If plants which guide the rainwater centripetally have petioled leaves, they have also a distinct channel on the upper side of the leaf-stalk, which is often deepened by the growth of a green border, or sometimes a dry border, on both edges. The channels on the stems of the radical leaves of Rhubarb (Fig. 10), Beet, Peony, and most Violets are especially interesting.

The arrangements of plants with cauline leaves for carrying off the water are much more complicated. When leaves on a stem high above the ground catch rainwater, as the Rhubarb does, they can keep their position better if their bases are joined directly to the stem, or clasp it. If such leaves were placed on long, upright stalks, they would require an immense bulwark of supporting cells, and, therefore, they are rarely petioled. Among well-known plants we can only name some

Pelargoniums (as P. zonale, House-Geranium). In most cases cauline leaves which lead the water centripetally are either sessile or short-stalked, and often clasp the stem with lobes or auricles.

If the leaves are opposite and decussating, the water is usually carried down in two channels, which run along the stem from one pair of leaves to the next. . . .

When the leaves are not opposite, but are arranged in a spiral, the water filters down the spiral from leaf to leaf. Many Thistles show this flowing off of the water along a spiral line very beautifully. With little grains of shot we may imitate the action of the raindrops, and by this means see very plainly, in plants with firm leaves, the path naturally taken by the falling drops. Such grains of shot dropped upon a growing plant of Alfredia (Fig. 11),[1] will roll down over the concave surface of the upper leaf, and strike the stem which the leaf clasps. Then, rolling over a lobe of the base of the leaf, it will fall on the middle of the surface of the leaf below, because the clasping auricles of each leaf lie over the middle of the next lower leaves. Thence the grains of shot fall on the third leaf, and so on, till they reach the earth close to the stem. The raindrops naturally follow the same path as the shot, but in their case not only

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[1] The Alfredia is a kind of thistle (*Carduus cernuus*).

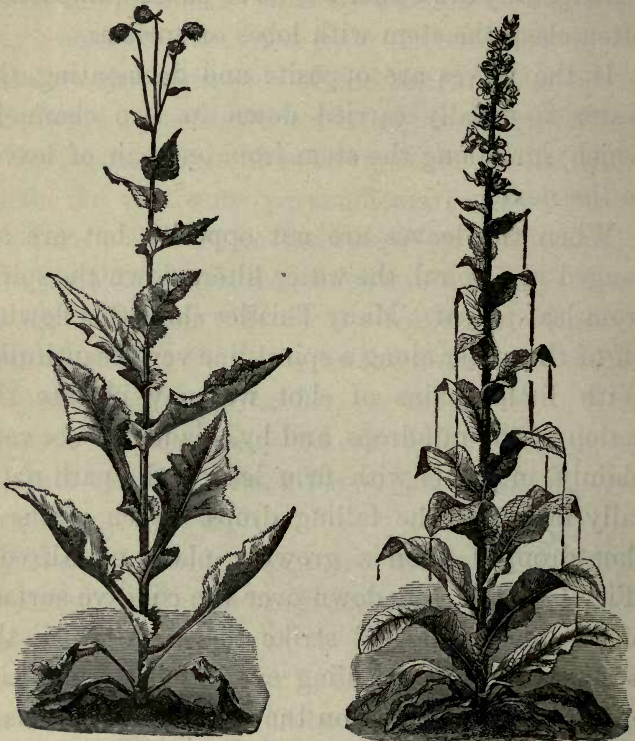

FIG. 11. GUIDING OF THE RAINWATER.

1. In the Alfredia (1). 2. In the Mullein (Verbascum phlomoides). ("Pflanzenleben.")

the first leaf, but every leaf, is covered with drops, and thus the stream, flowing from leaf to leaf, is continually reinforced and becomes greater and greater. . . .

A slightly different method of guiding the rain-water may be seen in the Mullein (Fig. 11).[1] The upper leaves, half clasping the stem, are upright, like those of the Alfredia, and guide the water downward in the same way. But the leaves in the middle portion of the stem are only upright for two-thirds of their length. The upper third is recurved, and the rain which falls on this upper third drops from the points of the leaves, and would thus seem to run off centrifugally. But the shape of the plant is a slender pyramid, as the leaves grow continually smaller towards the top of the stem, and the water drops from the apex of one leaf to the portion of the next lower leaf which slopes inward, and thus leads the water centripetally. In this way, the whole of the rainwater falling on such a plant finally reaches the neighborhood of the tap-root, and is used to the best advantage by the rootlets proceeding from it. . . .

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[1] Our species of Mullein, *Verbascum thapsus*, carries off the rain-water in the same manner. An experimenter has told me that it is necessary to cultivate plants by themselves in order to see this relation in the position of leaves and rootlets, for in the woods and fields so many conditions enter into the result that the growth of the roots may be determined by other causes. — ED.

The guiding of the water to the rootlets is of the greatest importance, for the water is not only absorbed by them, but is carried, as we shall see later, over the whole plant. . . .

In the building up of the molecules of sugar, of starch, of cellulose, and of all important substances out of which the plant is formed, the atoms of water are used as building stones, and without water no growth could take place. From this point of view water must be regarded as an indispensable foodstuff of plants, no less than the carbonic acid of the air. Water, however, plays another weighty part in the life of the plant. The mineral salts which nourish water-plants, earth-plants, and air-plants, as well as the organized food on which parasitic plants feed, can be taken up only in solutions. The salts can pass through the cells only when their walls are saturated with water, and must be dissolved in water in order to be brought into the interior of the plant wherever they are needed. Water acting in this capacity in living plants is to be regarded as the motive power. As the mill by the brook works only when its wheels are put in motion by the water, so the living, growing plant demands a great quantity of available water in order that its complicated life processes may be carried on. This water will not be chemically bound, like that which is used in food, and will not long be retained. We must conceive that water is continually streaming through the living plant. In the course of a summer, an amount of water passes through the plant which many times exceeds its weight. The water which is chemically united with the organic compounds of the plant, is extremely slight in comparison with that used in carrying its food materials. . . .

It is therefore plain, as water is a necessary food, and is needful in transporting other food materials, that a sufficient supply is indispensable to the life of the plant.[1]

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[1] "Pflanzenleben," I. pp. 199, 200.

VII.

TREES IN WINTER.

In Northern America we rejoice in a yearly spectacle which exceeds in richness and variety of color any other forest scene in the world. As September advances, the Swamp Maples and Sumachs clothe themselves in flaming red; then the Elms, Birches, Chestnuts, and, later, the Beeches, imitate the sunshine; lastly, the Oaks turn with a variety of rich, deep hues, which are the most beautiful and satisfying of all. The reason of this brilliancy of coloring, so much more striking than the woods of Europe, is not understood, although it is often attributed to the greater dryness of the climate.

It is a common mistake to suppose that the coloring of autumn leaves is due to frost. In mild seasons the trees are often completely turned before the thermometer has once sunk below the freezing-point. The first change of color is a sure sign that the tree is preparing for the winter, and that a change in the cell-contents of the leaves has begun.[1]

The process of making food is carried on in these leaf-cells. "They are the factories where starch, or something very similar, is made."[2] The raw material brought from the ground is here changed into food, on which plants and animals can live. Throughout the summer food has been constantly made and carried from the leaves to other parts of the plant, where it has been used for food, or stored as a reserve for the future. When this activity ceases, and the leaves fall from the tree, it would be a great waste of valuable material if all the food contained in their cells were to be lost. Nature permits no such waste. In autumn, when the life of the leaf is nearly at an end, its food materials are withdrawn and deposited in the stem and branches, for use in the following spring. This withdrawal is preceded by the breaking up of the contents of the cells. The chlorophyll — the green coloring-matter of the leaves — is decomposed; and the products of this change, together with the starch and other food materials, are taken into the interior of the tree. A little yellow or red coloring-matter is left behind, and it is this which gives the leaves their bright hues. When they finally fall, they are mere dead husks, emptied of nourishment, and of no further use to the plant.

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[1] Sachs, "Die Entleerung der Blätter im Herbst." *Flora.* 1863. p. 200.

[2] "Concerning a Few Common Plants." By G. L. Goodale. Boston: D. C. Heath & Co. 1886. p. 30.

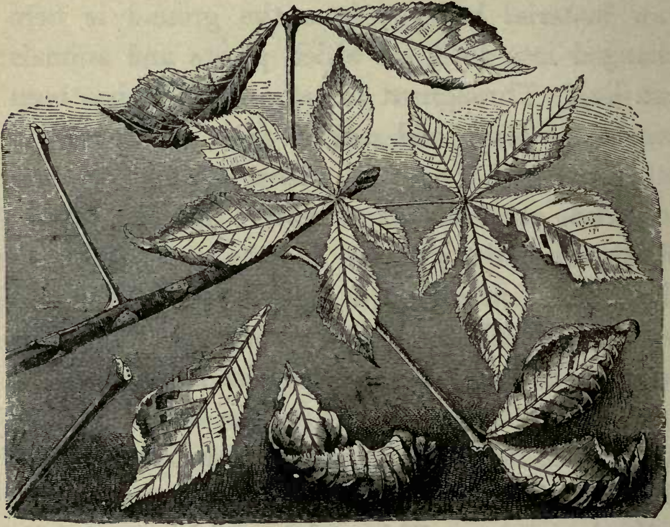

FIG. 12. FALL OF THE LEAF. HORSECHESTNUT. ("Pflanzenleben.")

When the leaf falls, a scar is left behind. In plants with compound leaves, like the Horsechestnut or the Ash, there is a similar scar at the base of each leaflet (Fig. 12). The process which causes the fall is a curious and interesting one, and it begins very early in the life of the leaf. At the base of each leaf-stalk a layer of cells is formed which gradually cuts across the whole petiole, and finally completely separates the leaf from its stalk, so that a gust of wind, or the mere weight of the leaf, is sufficient to cause it to fall. The walls of the cells of this separating layer generally become thickened and waterproof before the leaf falls, so that the scar is already healed.

This process, then, is one that is a part of the life-history of the leaf, and is not caused by changes in temperature. In climates where the plants are active during the entire year, the leaves fall gradually. As new leaves are formed, the old are dispensed with, and there is never a time when the plants are leafless. But in our climate most of the trees and shrubs are leafless for a large portion of the year. This is a provision which enables the plants to live through a long period of cold. By the loss of their leaves, and the withdrawal into safe places of all their food materials, the plants are able to survive uninjured. The fall of the leaves is hastened, although not caused, by the cold. We do not understand exactly why the leaves all fall at once; we can only say, that in our climate, probably those plants have survived and increased which were so constituted that a long period of rest succeeded a season of active work.[1]

In countries where a wet season is followed by a hot, dry season, the plants lose their leaves when the heat begins. Thus excessive cold and excessive heat produce the same effect.

Another advantage to the plants in losing their leaves is the lessened resistance which the tree presents to storms, and especially to snow. The weight of the winter snows would break the trees if the leaves were obliged to carry such a load. We sometimes see trees badly injured in this way by a premature snowstorm.

Now that the trees are divested of their summer dress, we see that the provision for the next season's garment has been already made. There are the buds thickly studding the branches. Look at the strong Horsechestnut buds, with their resinous, waterproof covering, and think of the wonderful sleep of the leaves within, wrapped in their woollen blankets, and awaiting only the warmth and moisture of spring to burst into renewed vigor (Fig. 13). After one has studied naked branches,

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[1] "Pflanzenleben," I. p. 329.

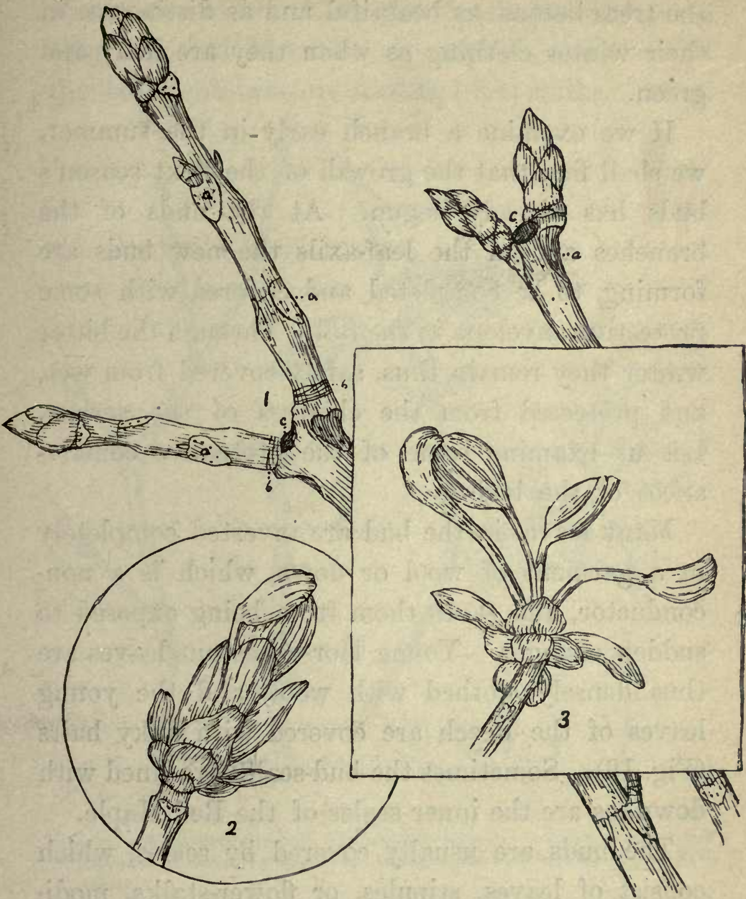
a
a
a
a
c
c
b
b
1
2
3

FIG. 13. HORSECHESTNUT.

1. Branch in Winter State. 2. An Expanding Leaf-Bud. 3. Same, more advanced.

the trees become as beautiful and as distinctive in their winter clothing as when they are leafy and green.

If we examine a branch early in the summer, we shall find that the growth of the next season's buds has already begun. At the ends of the branches and in the leaf-axils the new buds are forming, to be completed and covered with some protective envelope in the fall. Through the bitter winter they remain thus, safely covered from wet, and protected from the changes of the season. Let us examine some of the protective contrivances of the buds.

Many leaves in the bud are invested completely in a garment of wool or down, which is a non-conductor, and saves them from being exposed to sudden changes. Young Horsechestnut leaves are thus densely clothed with wool, and the young leaves of the Beech are covered with silky hairs (Fig. 19). Sometimes the bud-scales are lined with down, as are the inner scales of the Red Maple.

The buds are usually covered by scales, which consist of leaves, stipules, or flower-stalks, modified for the purpose of protection. In the Lilac the scales pass so gradually into leaves, that it is hard to draw any distinction between them (Fig. 14).

The scales of the Elm, the Beech, the Tulip-tree (Fig. 18), and Magnolia are stipules, and those of the Horsechestnut are modified leaf-stalks. In all these cases the outer scales have become thickened and hardened, so as the better to protect the bud. Often they are covered with resinous or waxy

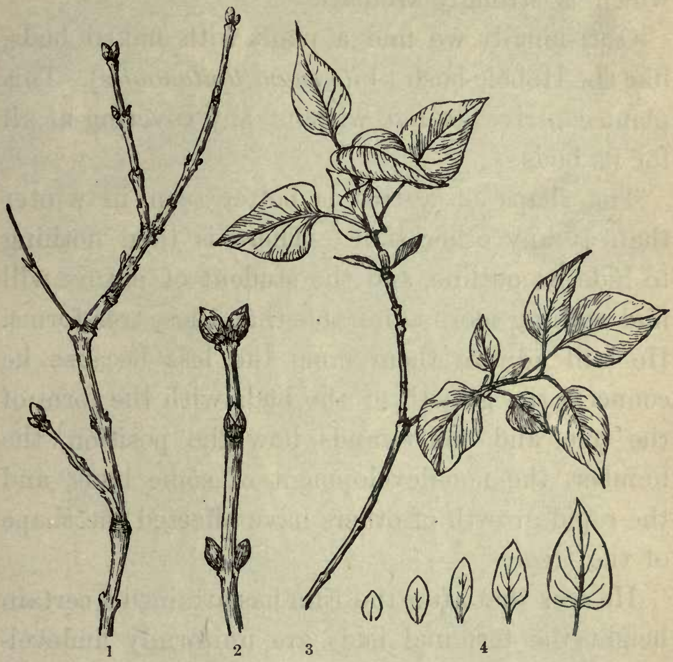

FIG. 14. LILAC.

1. Branch in Winter State (reduced). 2. Same, less reduced. 3. Branch, with Leaf-Buds expanded. 4. Series in a Single Bud, showing the Gradual Transition from Scales to Leaves.

matter to keep out the wet more effectually, as in the Horsechestnut. The Balm-of-Gilead has bud-scales thickly covered with a yellow substance, which is strongly aromatic.

Occasionally we find a plant with naked buds, like the Hobble-bush (*Viburnum lantanoides*). This plant contrives to live without any covering at all for its buds.

The shape of a tree is better seen in winter than at any other time. There is then nothing to hide its outline, and the student of nature will find nothing more admirable than these tree-forms. He will admire them none the less because he connects the growth of the buds with the form of the tree, and understands how the position, the number, the non-development of some buds, and the rapid growth of others have affected the shape of the tree.

He sees that after the Elm has attained a certain height the terminal buds are uniformly undeveloped, and that the axillary buds are exceedingly numerous. This makes the branches dissolve into many shoots, and these into finer spray, and helps to give the tree its exquisite grace (Fig. 15). When he looks at the rough bough of a Horsechestnut, he recognizes that the flower-clusters have contin-

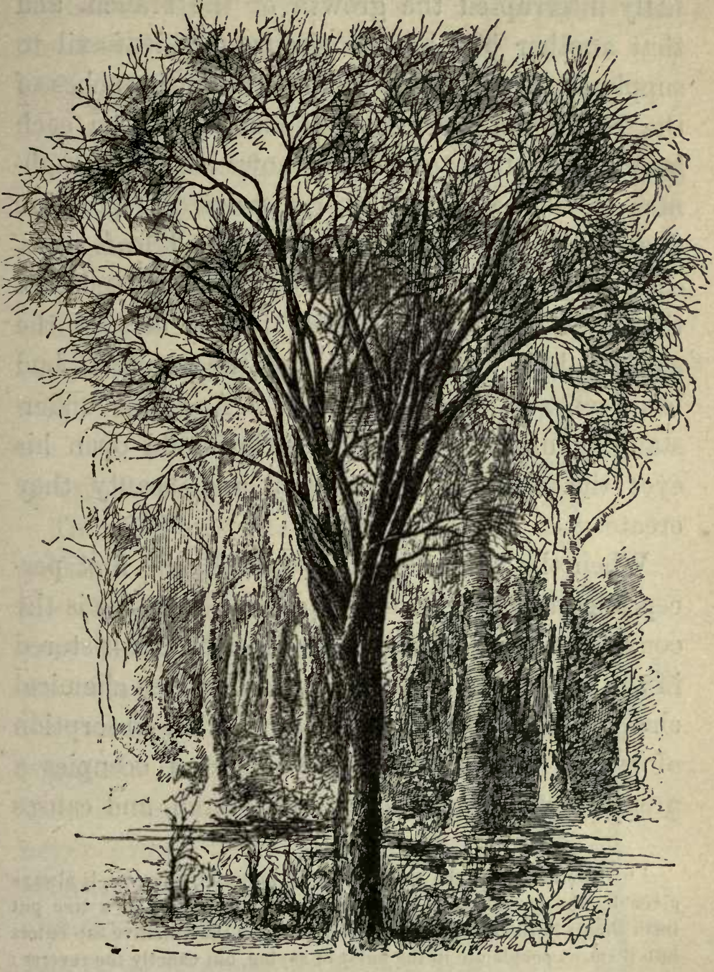

FIG. 15. ELM TREE IN WINTER.

ually interrupted the growth of the branch, and that another bud has grown from a leaf-axil to supply its place; while in the straight branches of the Beech the terminal bud has carried on each bough year after year. He knows that the roughness of the apple and cherry twigs (Fig. 16) are due to the multiplication of bud and leaf scars, caused by the very small yearly growth; and that the Lilac-bush is continually forked because the axillary buds have grown and the terminal bud has been suppressed (Fig. 14). And this understanding of the ways of growth should open his eyes the more to the variety and beauty they create.

When the winter is safely passed, the first perceptible change that takes place in the tree is the conversion of the dry, starchy food materials stored in the branches into a sugary sap.[1] This chemical change is largely brought about by the absorption of water. The liquid thus produced occupies a greater space than did the dry starch, and causes a pressure which forces the sap into every twig of the tree. The most familiar illustration of the flow of sap in the spring is the Sugar-Maple. The pressure of the sap forces a stream of liquid to flow from holes bored in the bark of the tree. The old idea that the sap descends into the root of a tree in the fall, and rises in the spring, is erroneous.

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[1] "The stimulus to the movements of material, however, is always given by the growth of the young organs. The buds of a tree put forth shoots in the spring by no means because the nutritive sap enters into them, as people are in the habit of saying, but exactly the reverse: the nutritive matters are set in motion because the buds begin to grow." Sachs, "Lectures on the Physiology of Plants," p. 364.

Then follows the most striking phenomenon of the whole year. The mild days come. The supply of food in the twigs is drawn up by the buds; they swell, they burst, and the leaves begin to expand. A single week has wrought a miracle whose wonder never grows less. It has always been the symbol of spiritual renewal and the source of poetry, and it will ever be so, however far we may trace the physical causes of the change.

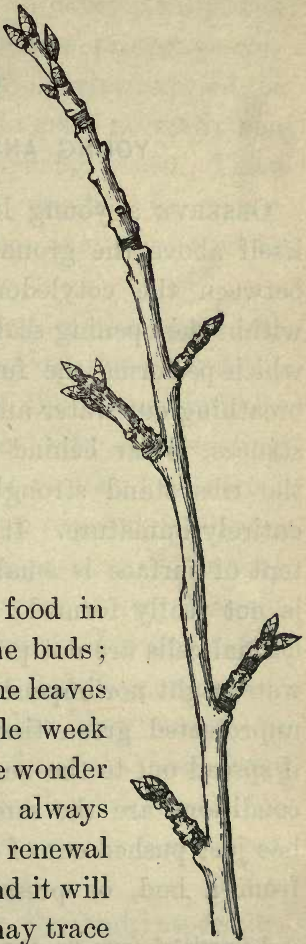

FIG. 16. BRANCH OF CHERRY.

VIII.

YOUNG AND OLD LEAVES.[1]

OBSERVE a young leaf which has just raised itself above the ground, or one still half hidden between the cotyledons of a seedling, or lying within the opening scales of a bud. The very part which performs the functions peculiar to the leaf, breathing out water and producing organized substances, is far behind in its development; while the ribs stand strongly out, the green tissue is entirely immature. It is not merely that the extent of surface is small, but the skin of the leaf is not really formed; the outer walls of the epidermal cells are not protected by cork, are neither water-tight nor impenetrable by water-vapor. This unprotected green tissue would soon become dry if spread out to the sunshine and the wind. The conditions are the same whether the young leaf has just pushed out of the ground, or is expanding from a bud, or pressing out from between the cotyledons. It takes some time for the parts which hold the green tissue to develop fully, and therefore it requires very effective protective contrivances to allow the young leaves, exposed to the changes of the weather, to grow normally and form unhurt their green, transpiring tissue. These contrivances are sometimes peculiar to young, undeveloped leaves; sometimes they may also be observed in full-grown leaves.

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[1] Translated from the German of Dr. A. Kerner von Marilaun. "Pflanzenleben." Vol. I. p. 321.

The diminution of the extent of the upper surface, which is directly exposed to the air and the wind, the vertical position of the leaves, and the covering of the green tissue under a protecting mantle are the most important means of defence.

The small amount of surface exposed to the air and sun is necessitated by the position of the leaf in the bud. In the bud the room is very limited, and the leaves are packed tightly into this room, so that their surfaces are rolled, folded, or crumpled. This is also an advantage when they emerge to the light of day: it prevents the green tissue from becoming dry, is continued until other protective appliances are formed, and remains in some cases throughout the life of the plant.

Many leaves are rolled in the bud, especially in bulbous plants. The midrib, or often quite a wide strip in the middle of the leaf, remains flat, but the margins are rolled up, sometimes on the upper, sometimes on the under side. The side on which the stomata are most numerous and the green, transpiring tissue is pierced with air-passages, is always concave. In the Crocus the two margins are rolled outwards and united by a broad, white, flat stripe, and in the Star-of-Bethlehem (*Ornithogalum*), whose leaves are marked with a similar white stripe, the halves are rolled inwards. In the Crocus the stomata are on the under side, in the Star-of-Bethlehem on the upper side of the leaf. The young leaves of Ferns are also rolled together, but the midrib, instead of being flat, is rolled inward spirally, like a watch spring, so that the green segments, springing from either side of the midrib, are packed closely one upon the other. Less common than leaves which are rolled are those which are crumpled in the bud. Here the netted veins make a firm trellis work, or grating, in the meshes of which the green tissue of the leaf appears as if blistered, and the whole leaf has the effect of a crumpled cloth. This is called *corrugate* or crumpled vernation. Especially striking in this respect are the young leaves of many species of Dock (*Rumex*), Rhubarb (*Rheum*), and some Primroses (*Primula*). A leaf is often both crumpled and rolled, the crumpled leaves having their margins rolled up in the bud.

The commonest kind of vernation is folding. In this form the ribs are flat, and only the green tissue between the ribs lies in folds. The manner of folding varies according to the form and distribution of the ribs of the leaf. When the leaf has many radial ribs, like the Lady's Mantle (*Alchemilla*, Fig. 17[7]), the leaf is folded in the bud like a fan. The ribs, which in the full-grown leaf diverge like rays, lie side by side, and the tissue, which eventually is stretched out flat, makes deep folds, pressed one upon the other. If each of the ribs makes the midrib of a segment, as in Five-finger (*Potentilla*) and Oxalis (Fig. 17[8]), the folding is the same; each leaflet is folded along the midrib like a sheet of paper, and these folded leaflets lie together like the sheets of paper in a box.

When the leaves are feather-veined and the leaflets are opposite each other on a common stalk, like the leaves of Rose and Walnut (Fig. 17[3, 4]), they are folded together along the midrib and laid one upon the other. In the Rose the common stalk is so short in the bud that the leaflets all seem to come from the same point like the Potentilla. In most Maple leaves the folding is not along the ribs, but along the short side nerves. Between these large folds are smaller ones, and so this form

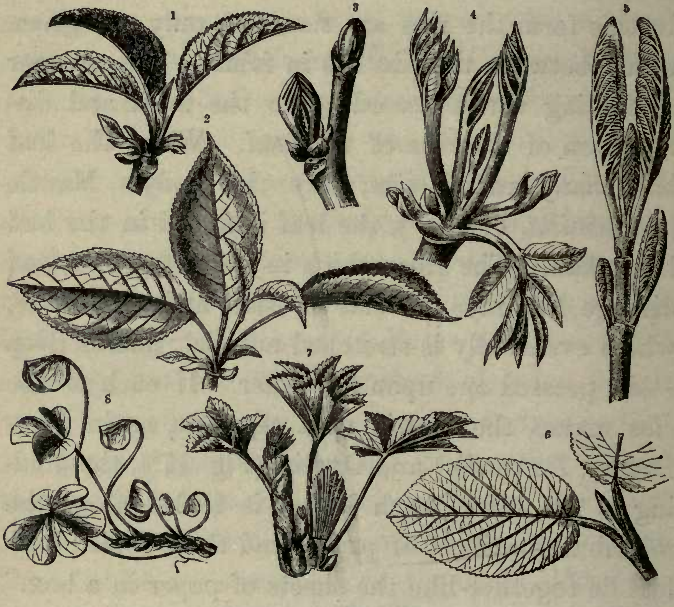

FIG. 17. VERNATION.

1, 2, of the Cherry (Prunus Avium); 3, 4, of the Walnut (Juglans regia); 5, 6, of the Snowball (Viburnum Lantana); 7, of the Lady's Mantle (Alchemilla vulgaris); 8, of the Wood-Sorrel (Oxalis acetosella). ("Pflanzenleben.")

of vernation makes a connecting link with corrugate vernation.

The folding of the leaves of the Beech, the Oak, and many other plants is peculiar. Every leaf has a midrib with the veins running out on either side, like the bones on the vertebral column of a fish. The green tissue makes deep folds between these veins, which lie upon each other like the folds of a fan (Fig. 19). The folding is different in the Cherry (Fig. $17^{1, 2}$). Every leaf is folded along the midrib in the bud, and remains so for some time after it has expanded. The two halves lie so close together and cover each other so perfectly, that at first sight they appear to be one. Besides this, they are firmly united by a balsam-like substance. They are also always erect in this stage of their development, which brings us to another contrivance which can be observed in young, undeveloped leaves.

We may affirm that except in the case of a few corrugate forms, the surfaces of young leaves, whether escaping from the earth, the cotyledons, or the bud, are never parallel with the ground. The green, transpiring, tender parts, especially, have always at first a vertical position, and their surfaces are turned sideways, as in stems which serve the purpose of leaves (*phyllocladia* and *phyllodia*[1]),

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[1] These are stems or petioles which serve as leaves. *Myrsiphyllum,* known in our greenhouses as Smilax, is an example of a branch acting the part of a leaf, and in Acacia the adult foliage is formed of leaf-stalks.

the equitant leaves of Iris, the leaves of the Compass Plant,[1] and the folded leaves of Grasses in dry weather. Either the whole outspread or rolled surface of the leaf is erect, as in most bulbous plants, or the midrib of the leaf may be bent towards the horizon. In the latter case, the two margins make a single edge, turned away from the rays of the midday sun, as in some Grasses (*Glyceria*, *Poa*) and in the Cherry-tree. Sometimes the petiole is upright, and the tender tissue is drawn down over it like a shut umbrella, as in Podophyllum, and several of the Crowfoot family. In the Horsechestnut the folded segments of the leaves issuing from the bud are upright; then they droop, so that their points are directed to the earth; and later, when their epidermis is more thickened, they raise themselves again till they are nearly parallel with the ground. Sometimes the upward-growing petiole is bent over in the form of a bow, and the folded leaves hang vertically on the curved end, as in the common Oxalis (*Oxalis acetosella*) and many other plants (Fig. 17[8]).

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[1] The blades of the Compass Plant (*Silphium laciniatum*) take a vertical position, by the leaves making a half twist. On the prairies the direction of the leaves is usually north and south.

Screens and coverings of various kinds are another form of protection for the tender undeveloped parts of young leaves. This covering is usually formed of stipules, which in Beeches, Lindens, Oaks, Magnolias, and many other plants are membranaceous, pale, and almost destitute of chlorophyll. They form scales, which envelop the young leaves pressing from the bud, which they often protect from the rays of the sun. When the leaf has outgrown this covering and needs it no longer, the scales wither, detach themselves, and fall to the ground. In Oak and Beech woods as soon as the leaves have reached their normal size, millions of such scales, which are called by botanists "deciduous stipules," may be found. Very deciduous are the stipules of the Tulip-tree (Fig. 18), a kind of Magnolia, native in North America, but now cultivated in every part of Europe. The stipules are large, scaly, and placed together in pairs, so as to form a sort of sack. In this membranaceous, somewhat transparent sack is enclosed the young leaf, whose stalk is bent over upon itself, and whose blade is folded along the midrib, like the leaf of Cherry. The leaf grows there, as if in a little hothouse, till the cells of its skin are so thick that there is no more danger of its becoming dried up. Then the sack opens, the two scaly stipules fall apart, shrivel, and finally

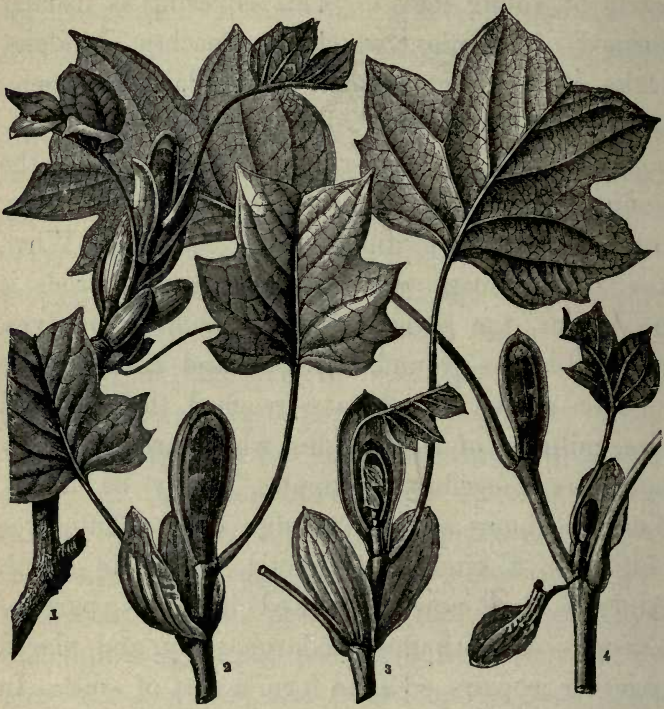

Fig. 18. VERNATION OF THE TULIP-TREE (Liriodendron Tulipifera).
("Pflanzenleben.")

fall off. There remain only two scars at the base of the leaf-stalk to remind us that here in spring were two stipules, which protected the tender young leaves from too great evaporation of water.

The coats of resin that often appear on young leaves also preserve them from too great evaporation, and when the leaf is fully expanded and the skin has become thickened, they finally disappear. It is a great protection for the leaves just escaped from the bud to be clothed with hairs. In a great many plants the leaves are only hairy in the beginning of their development. The Silver Poplar, the Pear, and the Mountain Ash are examples of this. The leaves of the Horsechestnut are thickly covered with wool when they push forth from the brown scales which they have forced apart, but they lose this wool in the course of the spring so completely, that in the full-grown leaves its former presence could only be guessed by a few shreds which hang here and there upon them. In the Beech (*Fagus sylvatica*, Fig. 19) the garment of the young leaves is formed of silky hairs, and their position and action are so peculiar that it is worth the trouble to examine the leaf more closely. At the first glance the young Beech leaf appears to be entirely clothed with silk on its under side, but on looking more closely, the silky hairs are to be found only on the margin and the side ribs, while the green tissue of the leaf is not hairy, but in fact perfectly bare. But as the green tissue of the leaf lies in deep folds, the ribs are brought very near together, and the long, silky hairs on one rib project far over the next, so that the furrows between are covered, and the effect of a leaf clothed wholly with silk is produced. There can be no doubt about the meaning of these hairs; they protect the tissue from the rays of the sun until the epidermis is sufficiently thickened. After this thickening has taken place, the folds straighten,

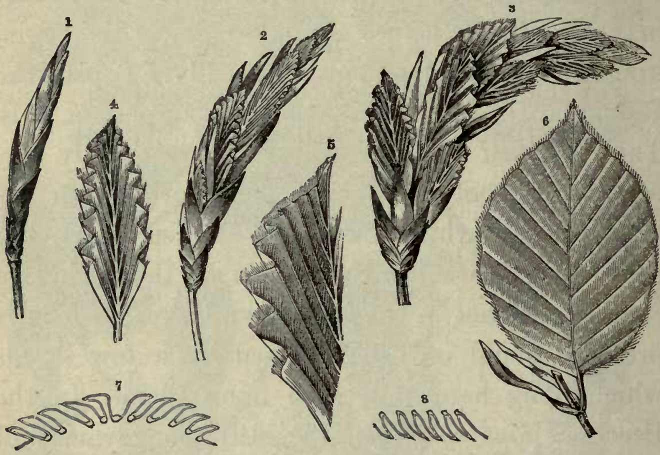

FIG. 19. VERNATION OF THE BEECH.

1. Bud beginning to expand. 2. Same, more advanced, showing the Leaves between the Scales. 3. Same, still more developed. 4. Back of a Young Beech Leaf, showing the Plicate Folding. 5. A Part of the Same Leaf, showing the Silky Hairs. 6. Upper Surface of Unfolded Leaf; the Stipules withered and about to fall. 7. Cross-Section of Leaf, perpendicular to the Midrib. 8. Vertical Section, parallel to the Midrib. ("Pflanzenleben.")

the leaf takes a horizontal instead of a vertical position, the lower side is turned away from the sun, and the role of the hairs is completed. They are now superfluous and drop off, or remain withered and meaningless.

IX.

LEAF-ARRANGEMENT.[1]

Mr. Ruskin, in one of his most exquisite passages, has told us that "Flowers seem intended for the solace of ordinary humanity: children love them; tender, contented, ordinary people love them. They are the cottager's treasure; and, in the crowded town, mark, as with a little broken fragment of rainbow, the windows of the workers in whose heart rests the covenant of peace." I should be ungrateful, indeed, did I not fully feel the force of this truth; but it will be admitted that the beauty of our woods and fields is due at least as much to foliage as to flowers.

In the words of the same author, "The leaves of the herbage at our feet take all kinds of strange shapes, as if to invite us to examine them, — star-shaped, heart-shaped, spear-shaped, arrow-shaped, fretted, fringed, cleft, furrowed, serrated, sinuated, in whorls, in tufts, in spires, in wreaths, endlessly expressive, deceptive, fantastic, never the same from footstock to blossom, they seem perpetually to tempt our watchfulness and take delight in outstripping our wonder."

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[1] "Flowers, Fruits, and Leaves." By Sir John Lubbock. Macmillan & Co. London, 1886. p. 97.

Now, why is this marvellous variety, this inexhaustible treasury of beautiful forms? Does it result from some innate tendency of each species? Is it intentionally designed to delight the eye of man? Or has the form, and size, and texture some reference to the structure and organization, the habits, and requirements, of the whole plant?

I do not propose now to discuss any of the more unusual and abnormal forms of leaves; . . . I propose, rather, to ask you to consider the structure, and especially the forms, of the common, every-day leaves of our woods and fields. . . .

In the first place, let us consider the size of the leaf. On what does it depend? In herbs we very often see the leaves decrease towards the end of the shoot; while in trees the leaves, though not identical, are much more uniform in size.

Again, if we take a twig of Hornbeam, we shall find that the six terminal leaves have together an area of about 14 square inches, and the section of the twig has a diameter of .06 of an inch. In the Beech the leaves are rather larger, six of them having an area of perhaps 18 inches; and, corresponding with this greater leaf-surface, we find that the twig is somewhat stouter, say .09 of an inch. Following this up we shall find that, *cæteris paribus*, the size of the leaf has a relation to the thickness of the stem. This is clearly shown in the following table: —

	Diameter of Stem in Inches.	Approximate Area of Six Upper Leaves in Inches.
Hornbeam	.06	14
Beech	.09	18
Elm	.11	34
Nut	.13	55
Sycamore	.13	60
Lime	.14	60
Chestnut	.15	72
Mountain Ash	.16	60
Elder	.18	93
Ash	.18	100
Walnut	.25	220
Ailanthus	.30	240
Horsechestnut	.30	300

In the Elm the numbers are .11 and 34, in the Chestnut .15 and 72, and in the Horsechestnut the stem has a thickness of .3, and the six leaves have an area often of 300 square inches. Of course, however, these numbers are only approximate. Many things have to be taken into consideration. Strength, for instance, is an important element. Thus the Ailanthus, with a stem equal in thickness to that of the Horsechestnut, carries a smaller area of leaves; perhaps because it is less compact. Again, the weight of the leaves must doubtless be taken into consideration. Thus, in some sprays of Ash and Elder of equal diameter, which I examined, the former bore the larger expanse of leaves. Not only, however, is the stem of the Elder less compact, but the Elder leaves, though not so large, were quite as heavy, if not, indeed, a little heavier. I was for some time puzzled by the fact that, while the terminal shoot of the Spruce is somewhat thicker than that of the Scotch Fir, the leaves are not much more than a third as long. May this not, perhaps, be due to the fact that they remain on the tree more than twice as long, so that the total leaf-area borne by the branch is greater, though the individual leaves are shorter? Again, it will be observed that the leaf-area of the Mountain Ash is small compared to the stem; and it may, perhaps, not be unreasonable to suggest that this may be connected with the habit of the tree to grow in bleak and exposed situations. The position of the leaves, the direction of the bough, and many other elements, would have also to be taken into consideration; but still it seems clear that there is a correspondence between thickness of stem and size of leaf. This ratio, moreover, when taken in relation with the other conditions of the problem, has, as we shall see, a considerable bearing not only on the size, but also on the form, of the leaf. . . .

Perhaps it will be said that in some trees the leaves are much more uniform in size than in others. This is true. The Sycamore, for instance, varies greatly. In the specimen tabulated its stem was .13 in diameter, and the area of the six upper leaves was 60 square inches. In another the six upper leaves had an area of rather over a hundred inches, and in this case the diameter of the stem was .18.

Another point is the length of the internode. In such trees as the Beech, Elm, Hornbeam, etc., the distance from bud to bud varies comparatively little, and bears a tolerably close relation to the size of the leaf. In the Sycamore, Maple, etc., on the contrary, the length varies greatly.

Now, if, instead of looking merely at a single leaf, we consider the whole bough of any tree, we shall, I think, see the reason of their differences of form.

Let us begin, for instance, with the common Lime (Fig. 20). The leaf-stalks are arranged at an angle of about 40° with the branch, and the upper surfaces of the leaves are in the same plane with it. The result is, they are admirably adapted to secure the maximum of light and air. Let us take, for instance, the second or third leaf in Fig. 20. They are 4½ inches long and very nearly as broad. The distance between the two leaves on each side is also just 4½ inches, so that they exactly fill up the interval. In *Tilia parvifolia* the arrangement is similar, but leaves and internodes are both less; the leaves, say, 1½ inch, and the internodes .6.

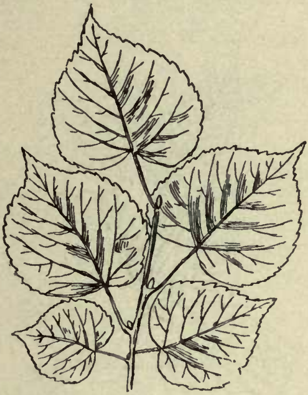

FIG. 20. LIME.

In the Beech the general plane of the leaves is again that of the branch (Fig. 21), but the leaves themselves are ovate in form, and smaller, being only from 2 to 3 inches in length. On the other hand, the distance between the internodes is also smaller, being, say, 1¼ inch against something less than 2 inches. The diminution in length of the internode is not, indeed, exactly in proportion to that of the leaf; but, on the other hand, the leaf does not make so wide an angle with the stem. To this position is probably due the difference of form. The outline of the basal half of the leaf fits neatly to the branch; that of the upper half follows the edge of the leaf beyond, and the form of the inner edge being thus determined, decides the outer one also.

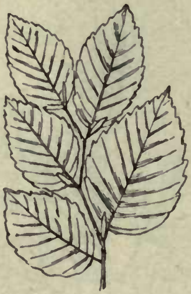

FIG. 21. BEECH.

In the Nut (*Corylus*) the internodes are longer, and the leaves correspondingly broader. In the Elm the ordinary branches have leaves resembling, though rather larger than, those of the Beech; but in vigorous shoots (Fig. 22) the internodes become longer, and the leaves correspondingly broader and larger, so that they come nearly to resemble those of the Nut.

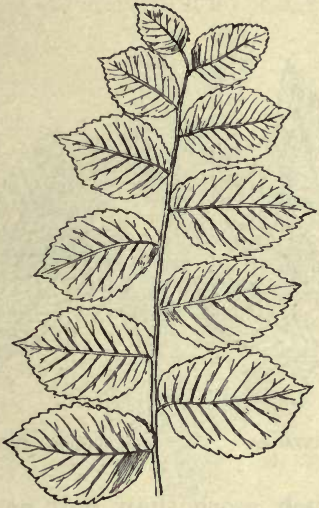

FIG. 22. ELM.

But it may be said that the Spanish Chestnut (*Castanea vulgaris*, Fig. 23) also has alternate leaves, in a plane parallel to that of the branch, and with internodes of very nearly the same length as the Beech. That is true; but, on the other hand, the terminal branches of the Spanish Chestnut are stouter in proportion. Thus, immediately below the sixth leaf, the Chestnut stalk may be .15 of an inch in thickness, that of the Beech not much more than half as much. Consequently the Chestnut could, of course supposing the strength of the wood to be equal, bear a greater weight of leaf; but, the width of the leaf being determined by the distance between the internodes, the leaf is, so to say, compelled to draw itself out. In Fig. 24 I have endeavored to illustrate this by placing a spray of Beech over one of

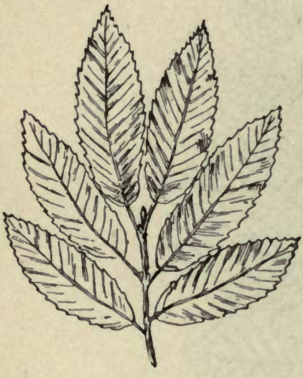

FIG. 23. CASTANEA.

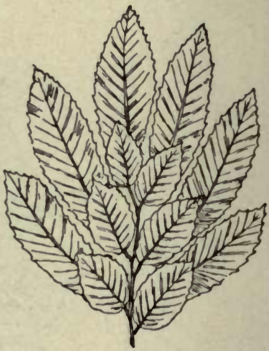

FIG. 24. CASTANEA AND BEECH.

Spanish Chestnut. Moreover, not only do the leaves on a single twig thus admirably fit in with one another, but they are also adapted to the ramifications of the twigs themselves. . . .

The leaves of the Yew (Fig. 25) belong to a type very different from those which we have hitherto been considering. They are long, narrow, and arranged all around the stem, but spread right and left, so that they lie on one plane, parallel to the direction of the branchlet, and their width bears just such a relation to their distance apart that when so spread out their edges almost touch.

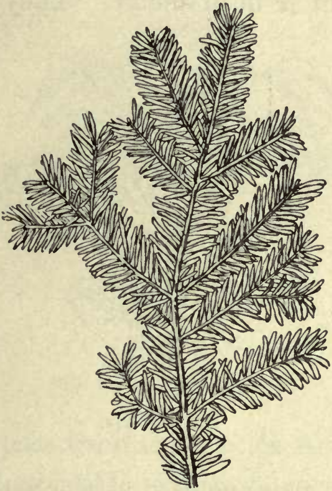

FIG. 25. YEW.

The leaves of Conifers are generally narrow and needle-like. I would venture to suggest that this may be connected with the absence of the fibro-vascular bundles, which are present in the stems of dicotyledons, such as the Beech, Oak, etc. The leaves of the Scotch Pine are needle-like, 1½ inches in length, and $\frac{1}{20}$ in diameter. They are arranged in pairs, each pair enclosed at the base in a sheath. One inch of stem bears about fifteen pairs of leaves. Given this number of leaves in such a space, they must evidently be long and narrow. If I am asked why they are longer than those of the Yew, I would suggest that the stem, being thicker, is able to support more weight. In confirmation of this we may take for comparison the

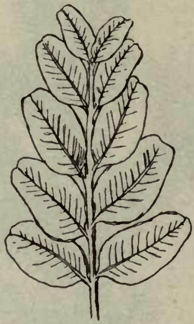

FIG. 26. BOX.

Weymouth Pine, in which the leaves are much longer and the stalk thicker.

Fig. 26 represents a sprig of Box. It will be observed that the increase of width in the leaves corresponds closely with the greater distance between the points of attachment.

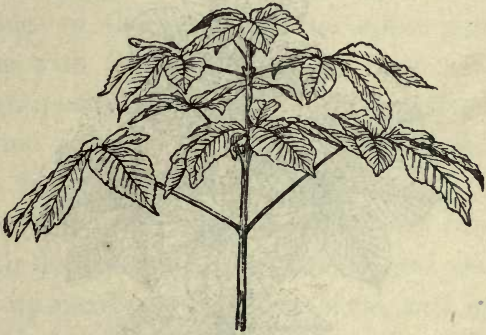

FIG. 27. HORSECHESTNUT.

When we pass from the species hitherto considered to the Maples (Fig. 29), Sycamores, and Horsechestnuts (Figs. 27 and 28), we come to a totally different type of arrangement. The leaves are placed at right angles to the axis of the branch, instead of being parallel to it, have long petioles, and palmate instead of pinnate veins. In this group the mode of growth is somewhat stiff; the main shoots are perpendicular, and the lateral ones nearly at right angles to them. The buds, also, are comparatively few, and the internodes, consequently, at greater distances apart, sometimes as much as a foot, though the two or three at the end of a branch are often quite short. The general habit is shown in Figs. 27 and 28. Now, if we were to imagine six Beech or Elm leaves on these three internodes, it is obvious that the leaf-surface would be far smaller than it is at present. Again, if we compare the thickness of an average Sycamore stem, below the sixth leaf, with that of

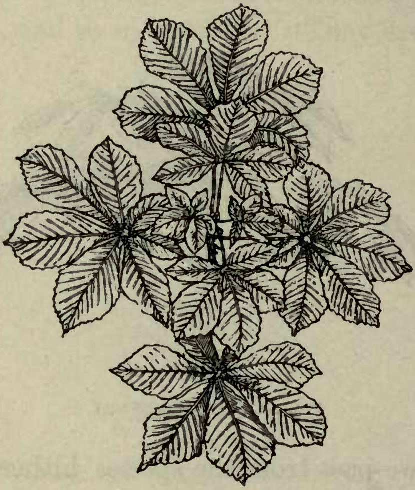

FIG. 28. HORSECHESTNUT.

a Beech stem, it is obvious that there would be a considerable waste of power. Once more, if the leaves were parallel to the branch, they would, as the branches are arranged, be less well disposed with reference to light and air. A glance at Figs. 27, 28, 29, however, will show how beautifully the leaves are adapted to their changed conditions. The blades of the leaves of the upper pair form an angle with the leaf-stalks, so as to assume a horizontal position, or nearly so; the leaf-stalks of the second pair decussate with those of the first, and are just so much longer as to bring up that pair nearly or quite to a level with the first; the third pair decussate with the second, and are again brought up nearly to the same level, and immediately to the outside of the first pair. In well-grown shoots there is often a fourth pair on the outside of the second. If we look at such a cluster of leaves directly from in front, we shall see that they generally appear somewhat to overlap; but it must be remembered that in temperate regions the sun is never vertical. Moreover, while alternate leaves are more convenient in such an arrangement as that of the Beech, where there would be no room for a second leaf, it is more suitable in such cases as the Sycamores and Maples that the leaves should be opposite, because if, other things remaining the same, the leaves of the Sycamore were alternate, the sixth leaf would require an inconvenient length of petiole.

Perhaps it will be said that the Plane-tree, which has leaves so much like a Maple that one species of the latter genus is named after it (*Acer platanoides*, Fig. 29), has, nevertheless, alternate leaves. In reality, however, I think this rather supports my argument, because the leaves of the Plane, instead of being at right angles to the stem, lie more nearly parallel with it. Moreover, as any one can see, the leaves are not arranged so successfully with reference to exposure as those of the species we have hitherto been considering, perhaps because, living as it does in more southern localities,

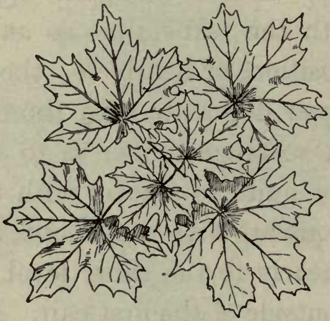

FIG. 29. ACER.

the economy of sunshine is less important than in more northern regions.

The shoot of the Horsechestnut is even stouter than that of the Sycamore, and has a diameter below the sixth leaf of no less than $\frac{3}{16}$ of an inch. With this increase of strength is, I think, connected the greater size of the leaves, which attain to as much as 18 inches in diameter; and this greater size, again, has perhaps led to the dissection of the leaves into five or seven distinct segments, each of which has a form somewhat peculiar in itself, but which fits in admirably with the other leaflets. However this may be, we have in the Horsechestnut, as in the Sycamore and Maples, a beautiful dome of leaves, each standing free from the rest, and expanding to the fresh air and sunlight a surface of foliage in proportion to the stout, bold stem on which they are borne.

Now, if we place the leaves of one tree on the branches of another, we shall at once see how unsuitable they would be. I do not speak of putting a small leaf, such as that of a Beech, on a large-leaved tree, such as the Horsechestnut; but if we place, for instance, Beech on Lime, or *vice versa,* the contrast is sufficiently striking. The Lime leaves would overlap one another; while, on the other hand, the Beech leaves would leave considerable interspaces. Or let us in the same way transpose those of the Spanish Chestnut (*Castanea*) and those of *Acer platanoides*, a species of Maple. I have taken specimens in which the six terminal leaves of a shoot of the two species occupy approximately the same area. Figs. 23 and 29 show the leaves in their natural position, those of the Spanish Chestnut lying along the stalk, while those of the Maple are ranged around it. In both cases it will be seen that there is practically no overlapping and very little waste of space. In the Spanish Chestnut the stalks are just long enough

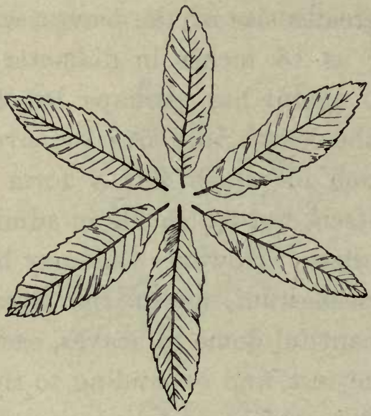

FIG. 30. LEAVES OF CASTANEA.

to give a certain play to the leaves. In Maple they are much longer, bringing the leaves approximately to the same level, and carrying the lower and outer ones free from the upper and younger ones.

Now, if we arrange the Spanish Chestnut leaves round a centre, as in Fig. 30, it is at once obvious how much space is wasted. On the other hand, if we place the leaves of the Maple on the stalk of a Spanish Chestnut at the points from which the leaves of Chestnut came off, as in Fig. 31, we shall see that the stalks are useless, and even mischievous as a cause of weakness and of waste of space; while, on the other hand, if we omit the stalks, or shorten them to the same length as those

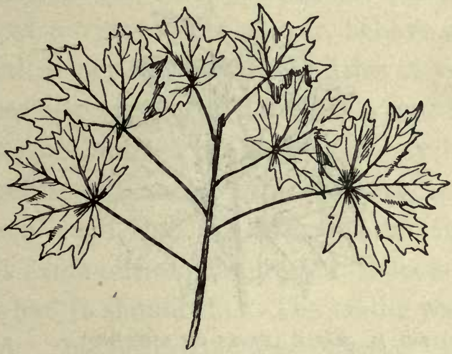

FIG. 31. MAPLE LEAVES ON CHESTNUT.

of the Chestnut, as in Fig. 32, the leaves would greatly overlap one another.

Once more: for leaves arranged as in the Beech the gentle swell at the base is admirably suited; but in a crown of leaves, such as those of the Sycamore, space would be wasted, and it is better that they should expand at once, as soon as their stalks have borne them free from those within. Moreover, the spreading lobes leave a triangular space (Fig. 29) with the insertion of the stalk at the apex, which seems as if expressly designed to leave room for the pointed end of the leaf within.

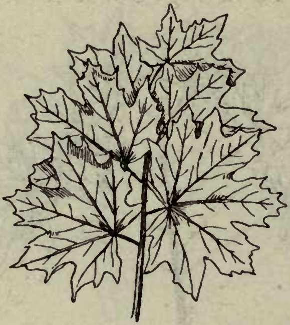

FIG. 32. MAPLE LEAVES ON CHESTNUT.

Hence we see how beautifully the whole form of these leaves is adapted to the mode of growth of the trees themselves and the arrangement of their buds.

X.

CLIMBING PLANTS.

CHARLES DUDLEY WARNER, in "My Summer in a Garden," gives the following description of the growth of a vine: "I, however, believe in the intellectual, if not the moral, qualities of vegetables, and especially weeds. There was a worthless vine that (or who) started up about midway between a grape-trellis and a row of bean-poles, some three feet from each, but a little nearer the trellis. When it came out of the ground, it looked around to see what it should do. The trellis was already occupied; the bean-pole was empty. There was evidently a little the best chance of light, air, and sole proprietorship on the pole; and the vine started for the pole, and began to climb it with determination. Here was as distinct an act of choice, of reason, as a boy exercises when he goes into a forest, and, looking about, decides which tree he will climb. And, besides, how did the vine know enough to travel in exactly the right direction, three feet, to find what it wanted? This is intellect."

This expresses very prettily a thing which every garden-lover must have noticed, — that a vine will find out its support anywhere within a reasonable distance. Of course, the choice between the trellis and the pole is a genial fancy of the gardener; but it is a fact that a plant with tendrils will find out and clasp a stick placed at a short distance from it on any side, and, similarly, that a Morning-Glory will wind about a pole in its neighborhood, on whichever side this may happen to be. The explanation of this curious phenomenon was sought and found by Charles Darwin, and he was led to study the subject in the following way.

In August, 1858, Dr. Gray read a short "Note on the Coiling of Tendrils" before the American Academy of Arts and Sciences.[1] In this paper he spoke of the views of a German, Hugo von Mohl, who had published a book on the subject twenty years before.[2] Von Mohl said that the coiling was due to an irritability excited by contact, that it was of the same nature as the closing of the leaves of the Sensitive Plant at the touch. Dr. Gray indorsed this view, and gave his own observations thus: —

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[1] "Proc. Amer. Acad. of Arts and Sciences." 1858.

[2] "Ueber das Bau und das Winden der Ranken und Schlingpflanzen." 1827.

"The tendrils in several common plants will coil up more or less promptly after being touched, or brought with a slight force into contact with a foreign body, and in some plants the movement of coiling is rapid enough to be directly seen by the eye; indeed, is considerably quicker than is needful for being visible. And, to complete the parallel, as the leaves of the Sensitive Plant and the like, after closing by irritation, resume after a while their ordinary expanded positions, so the tendrils in two species of the *Cucurbitaceæ*, or Squash family, experimented upon,[1] after coiling in consequence of a touch, will uncoil into a straight position in the course of an hour; then they will coil up at a second touch, often more quickly than before; and this may be repeated three or four times in the course of six or seven hours.

"My cursory illustrations have been principally made upon the Bur-Cucumber (*Sicyos angulatus*). To see the movement well, full-grown and outstretched tendrils, which have not reached any support, should be selected, and a warm day; 77 F. is high enough.

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[1] "Sicyos angulatus und Echinocystis lobata."

"A tendril which was straight, except a slight hook on the tip, on being gently touched once or twice with a piece of wood on the upper side, coiled at the end into 2½–3 turns within a minute and a half. The motion began after an interval of several seconds, and fully half of the coiling was quick enough to be very distinctly seen. After a little more than an hour had elapsed, it was found to be straight again. The contact was repeated, timing the result by the second-hand of a watch. The coiling began within four seconds, and made one circle and a quarter in about four seconds.

"It had straightened itself again in an hour and five minutes (perhaps sooner, but it was then observed); and it coiled the third time on being touched rather firmly, but not so quickly as before; viz., 1¼ turns in half a minute.

"I have indications of the same movement in the tendrils of the Grape-vine; but a favorable day has not occurred for the experiment since my attention was first directed to the subject."

This paper set Darwin also to studying climbers. In 1863 he writes to Sir Joseph Hooker:[1] —

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[1] "Life and Letters of Charles Darwin." By Francis Darwin. Vol. II. p. 484.

My dear Hooker, — I have been observing pretty carefully a little fact which has surprised me; and I want to know from you and Oliver whether it seems new or odd to you; so just tell me whenever you write: it is a very trifling fact, so do not answer on purpose.

I have got a plant of *Echinocystis lobata* [Fig. 33] to observe the irritability of the tendrils described by Asa Gray, and which, of course, is plain enough. Having the plant in my study, I have been surprised to find that the uppermost part of each branch (*i.e.*, the stem between the two uppermost leaves excluding the growing tip) is constantly and slowly twisting round, making a circle in from one-half to two hours. It will sometimes go round two or three times, and then at the same rate untwists and twists in opposite directions. It generally rests half an hour before it retrogrades.[1] The stem does not become permanently twisted. The stem beneath the twisting portion does not move in the least, though not tied. The movement goes on all day and all early night. It has no relation to light, for the plant stands in my window, and twists from the light just as quickly as towards it. This may be a common phenomenon for what I know, but it confounded me quite when I began to observe the irritability of the tendrils. I do not say it is the final cause, but the result is pretty; for the plant, every one and a half or two hours, sweeps a circle (according to the length of the bending shoot and the length of the tendril) of from one foot to twenty inches in diameter, and immediately that the tendril touches any object, its sensitiveness causes it immediately to seize it. A clever gardener, my neighbor, who saw the plant on my table last night, said: "I believe, sir, the tendrils can see; for wherever I put a plant it finds out any stick near enough." I believe the above is the explanation, viz., that it sweeps slowly round and round. The tendrils have some sense, for they do not grasp each other when young.

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[1] This reversal of the direction of the movement is not the normal method of the plant. He says of it afterward ("Climbing Plants," p. 128), "The course generally pursued was with the sun, but often in an opposite direction. Sometimes the movement during a short time would either stop or be reversed; and this apparently was due to interference from the light, as, for instance, when I placed a plant close to a window."

Yours affectionately,

C. DARWIN.

Here he has found the explanation of the curious fact which we noticed in the beginning of this article. Two years later his paper on "Climbing Plants" was printed in the Journal of the Linnæan Society, and in 1875 the essay was revised and published as a separate book.

Darwin divides climbing plants into four classes: (1) Twiners, or plants which climb by the stem winding about its support. (2) Leaf-climbers and tendril-bearers, plants which possess irritable organs by which they grasp any object with which they come in contact. (3) Hook-climbers. (4) Root-climbers, which attach themselves by means of aerial rootlets. The last two classes have no

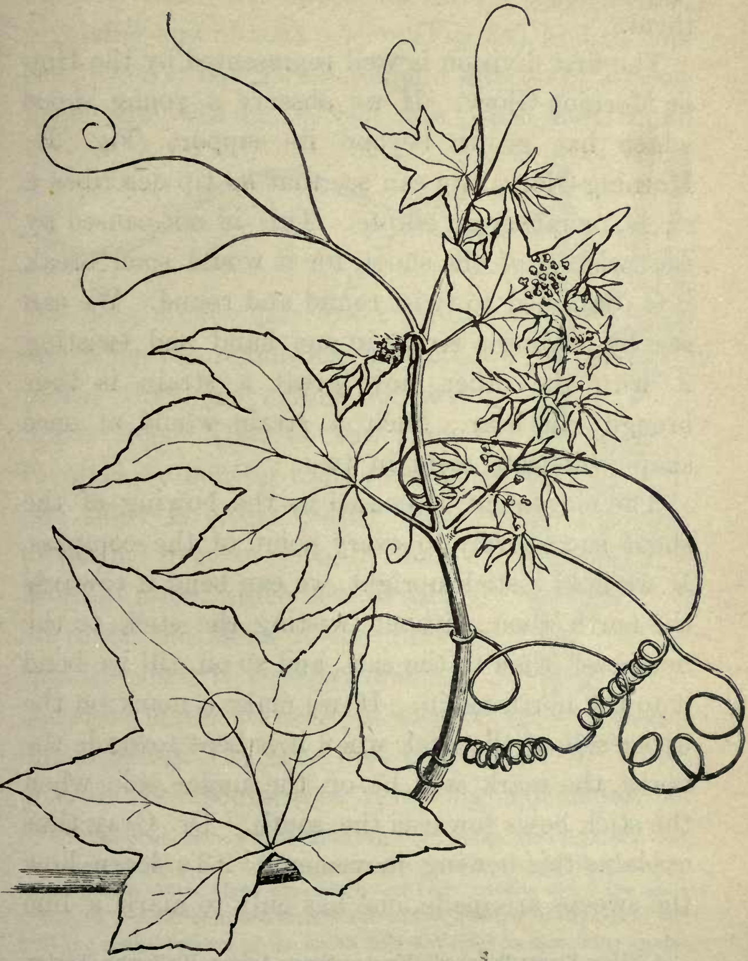

FIG. 33. ECHINOCYSTIS LOBATA (Wild Balsam-Apple, Cucumber-vine).

special movements, and we shall not here consider them.

The first division is well represented by the Hop or Morning-Glory. If we observe a young shoot which has grown beyond its support (Fig. 34, Morning-Glory), we can see that its tip describes a circle, or rather an ellipse. This is not caused by the twisting of the shoot, for it would soon break if it continued to twist round and round. We can see, by holding a string in one hand and twisting it with the other, how great a strain is thus brought to bear. Such a strain would at once snap a delicate stem in two.

The movement is caused by the bowing of the shoot successively to every point of the compass. If we hold a stick upright, we can bend it towards the north, then, without twisting the stick, to the northeast, then to the east, and so on, till we bend it to the north again. If we make a mark on the upper side of the stick when it is bent towards the north, the mark will be on the under side when the stick bows towards the south. Dr. Gray thus explains this bowing movement:[1] "To learn how the sweeps are made, one has only to mark a line of dots along the upper side of the outstretched revolving end of such a stem (Fig. 34), and to note that when it has moved round a quarter of a circle these dots will be on one side, when half round the dots occupy the lower side, and when the revolution is completed they are again on the upper side. That is, the stem revolves by bowing itself over to one side; is either pulled over, or pushed over, or both, by some internal force, which acts in turn all round the stem in the direction in which it sweeps; and so the stem makes its circuits without twisting."[1] "The first purpose of the spontaneous revolving movement, or,

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[1] "How Plants Behave." By Asa Gray. Ivison, Blakeman, Taylor, & Co. 1872. p. 13.

Louise S. Quackenbush

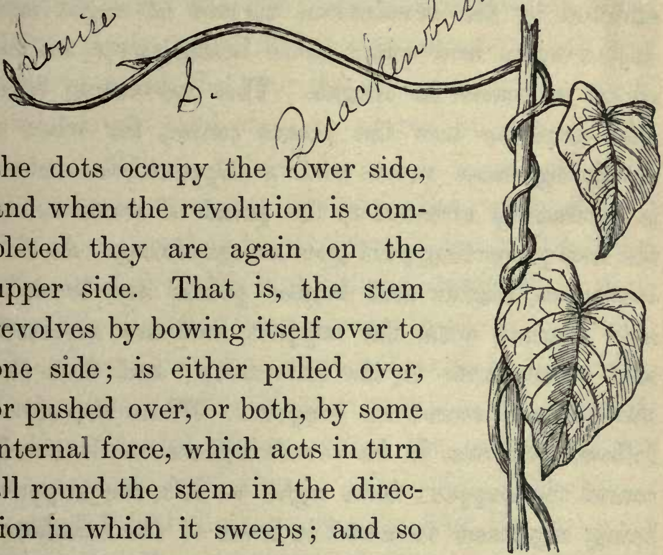

FIG. 34. MORNING-GLORY.

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[1] "The phenomenon finds its explanation in the fact that first one and then another side of the organ elongates more rapidly than the rest. If this takes place alternately on two opposite sides, the apex therefore bends over at one time to the left, at another to the right; but if at the circumference of the organ different sides in succession gradually take their turns in the process, then the pendent apex must rotate in space." — Sachs, "Lectures on the Physiology of Plants," p. 546.

more strictly speaking, of the continuous bowing movement, directed successively to all points of the compass, is, as Mohl has remarked, to favor the shoot finding a support. This is admirably effected by the revolutions carried on night and day, a wider and wider circle being swept as the shoot increases in length. This movement likewise explains how the plants twine, for when a revolving shoot meets with a support, its motion is necessarily arrested at the point of contact, but the free projecting part goes on revolving. As this continues, higher and higher points are brought into contact with the support and are arrested, and so onwards to the extremity; and thus the shoot winds round its support. When the shoot follows the sun in its revolving course, it winds round the support from right to left, the support being supposed to stand in front of the beholder; when the shoot revolves in an opposite direction, the line of winding is reversed. As each internode loses from age its power of revolving, it likewise loses its power of spirally twining."[1]

Darwin tried experiments with many twiners. In the case of one plant (*Ceropegia Gardnerii*) the revolving shoot was 31 inches long. "The extreme tip thus made a circle of above 5 feet (or 62 inches) in diameter and 16 feet in circumference, travelling at the rate of 32 or 33 inches per hour. The weather being hot, the plant was allowed to stand on my study-table; and it was an interesting spectacle to watch the long shoot sweeping this grand circle, night and day, in search of some object round which to twine."[1]

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[1] "The Movements and Habits of Climbing Plants." By Charles Darwin. D. Appleton & Co. 1888. p. 14.

Most twiners move around in the contrary direction from the hands of a watch, but a few move from the left to the right of the observer. In rare cases the direction may reverse in the same plant. This reversal happens frequently with leaf-climbers. *Tropæolum* (Garden Nasturtium) is a good example of this class of plants, where the petioles of the leaves clasp the support (Fig. 35). The young shoots of leaf-climbers revolve like the stems of twiners, and in some cases the leaves revolve also. "The object gained by the revolving movement is to bring the petioles, or the tips of the leaves, into contact with surrounding objects; and without this aid the plant would be much less successful in climbing. With rare exceptions, the petioles are sensitive to contact only whilst young. . . . They always bend towards the side which is pressed or touched, at different rates in different species, sometimes within a few minutes, but generally after a much longer period. After temporary contact with any object, the petiole continues to bend for a considerable time; afterwards it slowly becomes straight again, and can then re-act. A petiole, excited by an extremely slight weight, sometimes bends a little, and then becomes accustomed to the stimulus, and either bends no more, or becomes straight again, the weight still remaining suspended. Petioles which have clasped an object for some little time cannot recover their original position. After remaining clasped for two or three days they generally increase much in thickness,

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[1] "Climbing Plants," p. 6.

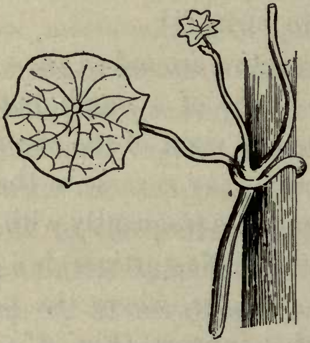

FIG. 35. TROPÆOLUM MINUS. (Sachs).

either throughout their whole diameter, or on one side alone; they subsequently become stronger and more woody, sometimes to a wonderful degree; and in some cases they acquire an internal structure like that of the stem or axis."[1]

In one species of *Tropæolum* examined by Darwin the first young leaves were like tendrils, without anything resembling a leaf-blade. As the plant grew older it produced these tendril-like filaments with enlarged tips, then with partly formed blades, and finally with perfect leaves. The filaments, as well as the perfect leaves, were very sensitive, and they moved spontaneously and contracted spirally, as do perfect tendrils. The plant would be called a tendril-bearer if it acted in this way when mature; but when full-grown it is a true leaf-climber. This shows us very plainly that tendrils are modified leaf-stalks. They may also be formed from modified branches or flower-stalks.

Plants with tendrils are wonderfully interesting in their perfect adaptation for purposes of climbing. The tendrils sweep round and round, and when they come in contact with a support, their sensitiveness to pressure makes them bend towards the object and clasp it. Then they begin to contract into a spiral, thus dragging the stem of the plant nearer to the support, and allowing other tendrils to grasp it also. The twist is in one direction for a number of turns, and then is reversed, so that the strain is not too great (Fig. 36). Besides bringing the shoot near its support, the spiral contraction is useful as rendering the tendrils elastic. "It is this elasticity which protects both branched and simple tendrils from being torn away from their supports during stormy weather. I have more than once gone on purpose, during a gale, to watch a Bryony, growing in an exposed hedge, with its tendrils attached to the surrounding bushes; and as the thick and thin branches were tossed to and fro by the wind, the tendrils, had they not been excessively elastic, would instantly have been torn off and the plant thrown prostrate; but, as it was, the Bryony safely rode out the gale, like a ship with two anchors down, and with a long range of cable ahead to serve as a spring as she surges to the storm [Fig. 36]."[1]

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[1] "Climbing Plants," p. 81.

When a tendril finds no support, it contracts into a spiral coil, and as the end is free the turns are all in the same direction (Fig. 36). In this case it soon withers; but if it has been able to take hold of any support, it becomes firmer and stouter

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[1] "Climbing Plants," p. 164.

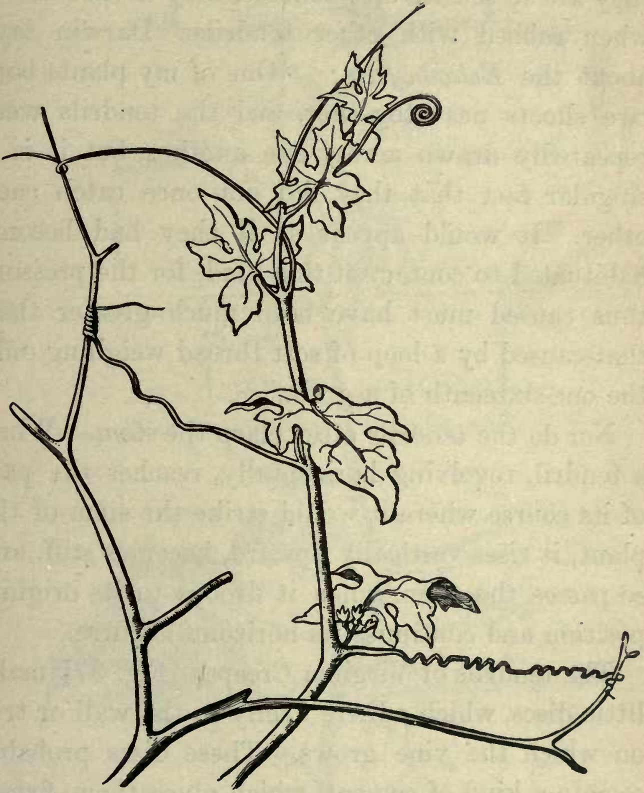

FIG. 36. WHITE BRYONY (Bryonia dioica). (Sachs.)

than before. If it does not clasp anything, it curls up into a simple spire and gradually withers away.

One of the strangest things about tendrils is that they do not often clasp each other. Although they are so sensitive to contact, they do not move when rubbed with other tendrils. Darwin says about the *Echinocystis:* "One of my plants bore two shoots near together, and the tendrils were repeatedly drawn across one another, but it is a singular fact that they did not once catch each other. It would appear as if they had become habituated to contact of this kind, for the pressure thus caused must have been much greater than that caused by a loop of soft thread weighing only the one-sixteenth of a grain." [1]

Nor do the tendrils often clasp the stem. When a tendril, revolving horizontally, reaches the part of its course where it would strike the stem of the plant, it rises vertically upward, becomes stiff, and so passes the stem, when it droops to its original position and continues its horizontal course.

The tendrils of Virginia Creeper (Fig. 37) make little discs, which adhere firmly to the wall or tree on which the vine grows. These discs probably secrete a kind of cement, which glues them firmly to the wall. If the tendrils do not become attached to anything, they soon wither and drop

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[1] "Climbing Plants," p. 131.

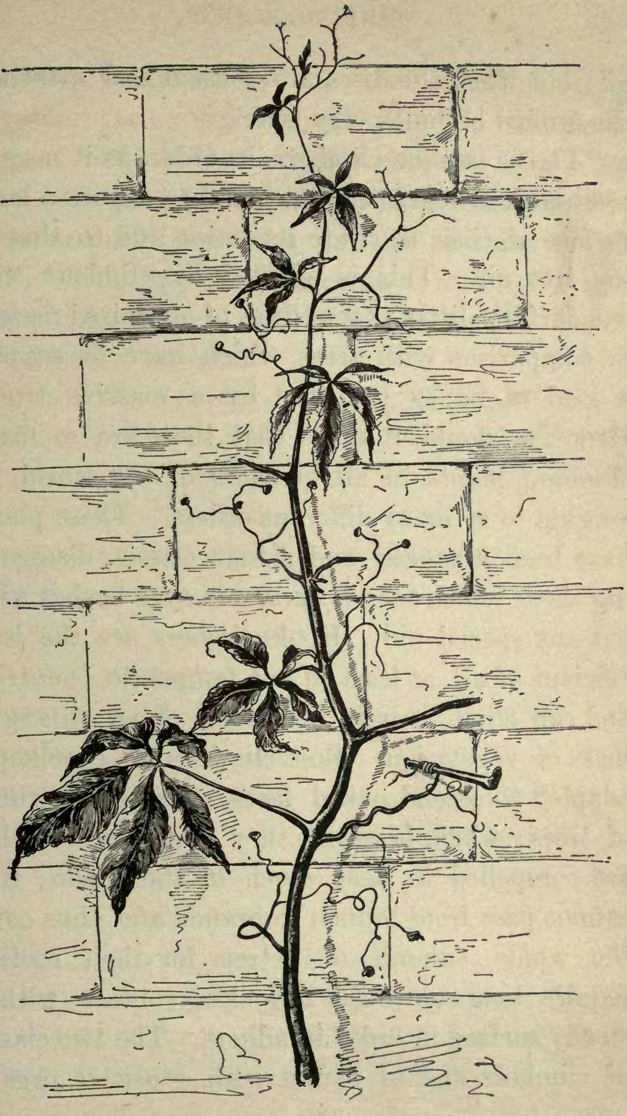

FIG. 37. VIRGINIA CREEPER (Ampelopis hederacea). (Sachs.)

off; but when the discs are formed and attached, the tendril becomes very strong.

"Plants become climbers, in order, as it may be presumed, to reach the light, and to expose a large surface of their leaves to its action and to that of the free air. This is effected by climbers with wonderfully little expenditure of organized matter, in comparison with trees, which have to support a load of heavy branches by a massive trunk. Hence, no doubt, it arises that there are so many climbing plants in all quarters of the world, belonging to so many different orders. These plants have been arranged under four classes, disregarding those which merely scramble over bushes without any special aid. Hook-climbers are the least efficient of all, at least in our temperate countries, and can climb only in the midst of an entangled mass of vegetation. Root-climbers are excellently adapted to ascend naked faces of rock or trunks of trees; when, however, they climb trunks, they are compelled to keep much in the shade; they cannot pass from branch to branch and thus cover the whole summit of a tree, for their rootlets require long-continued and close contact with a steady surface in order to adhere. The two classes of climbers and of plants with sensitive organs, namely, leaf-climbers and tendril-bearers taken together, far exceed in number and in the perfection of their mechanism, the climbers of the two first classes. Those which have the power of spontaneously revolving and of grasping objects with which they come in contact, easily pass from branch to branch, and securely ramble over a wide, sunlit surface."[1]

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[1] "Climbing Plants," p. 189.

XI.

PROTECTION OF THE GREEN TISSUE FROM THE ATTACKS OF ANIMALS.[1]

The cells of plants contain albuminoids similar to the white of egg, and in their green tissues are formed carbohydrates, such as starch and sugar, which are easily digestible. What wonder that numberless animals find this green tissue a very desirable food! Many animals, as is well known, live entirely at the expense of plants. In this respect the animal and vegetable kingdoms are hostile to each other, for the removal of all the green parts of the plant ensures its destruction, if its store of reserve food is exhausted. Hunger drives grazing animals to snatch the plants unmercifully, and thus completely destroy them. The beasts cannot foresee, as men do, that if the plant be robbed of all its green organs it will die, and that, consequently, in the following year, their own existence will be imperilled for lack of food. Man leaves enough of the plants which he uses to secure their growth and increase; nay, he himself assists their growth, and protects them at the cost of much labor from the attacks of animals. But only a very small proportion of the whole number of plants are thus cared for by man; the rest, from which he receives no advantage, must find means to protect themselves, or perish. These means of protection, it is true, are all defensive, so that the relation between plants and animals is not to be compared to a state of war, but rather to an armed peace.

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[1] Condensed extracts from "Pflanzenleben," Vol. I. p. 399.

Nevertheless these defences are often dangerous to the assailant, and they include poisons and corrosive fluids, as well as sharp weapons.

It is mysterious how grazing animals suspect the existence of poison in leaves. Sometimes poisonous plants have a strong odor which is disagreeable to men, as is the case with the Thorn-Apple (*Datura Stramonium*);[1] but many others, which are equally shunned by animals, have leaves which are scentless to us, as long as they are unbruised, like the Aconite, the Euphorbia, and the Gentians, which are never eaten by wild animals, nor by grazing flocks and herds. As long as they remain uninjured in field and wood, they have no odor perceptible to man; but animals must recognize these plants by the sense of smell, before they have bitten and injured them.

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[1] A good American example is the Skunk Cabbage (*Symplocarpus fœtidus*).

That the green leaves of the Rhododendrons and Azaleas, of the Partridge-Berry, the Bearberry, and of many other low evergreen plants, which form a large part of the vegetation of pastures and moors, as well as of the high mountain slopes, are avoided by grazing animals is explained by the fact that they are indigestible, owing to their tough skin, often containing silica. It is certain that the formation of a thick and hard cuticle, and the presence of silica in the epidermis is a means of protection against grazing animals, by which, of course, we do not mean to say that this structure has no other function.

Water is another excellent means of defence for many plants. The water which is collected by certain leaves from the rain and dew often remains in special receptacles for days and weeks. Ruminating animals do not graze in the morning when the grass is covered with dew, they wait till the cold drops are dried up, and even later in the day they avoid those plants on which drops are hanging.

But the most important means of defence to the plant against hungry animals are organs which run out into sharp, protruding points, ready to wound an aggressor. We may call these the weapons of the plant. They may be divided botanically into thorns and prickles. A thorn is an organ which runs out into a sharp spine, composed principally of woody tissue, or traversed by fibrovascular bundles. A prickle is an outgrowth from the skin of a plant, without woody bundles, one-celled or many-celled, always ending in a sharp point, capable of wounding an assailant. This distinction is not an important one and cannot always be maintained.

Spines and prickles appear on every possible portion of a plant. They are generally above or near the green tissue which they protect, but often the path leading to the green parts over leaf-stalks, stem, and sometimes aerial roots, is provided with prickles and thorns, in order to keep off the crawling creatures that eat the leaves, especially the snails. The lower parts of the stem up which they must climb to reach the green tissue are armed with thorns and prickles in many plants, as in Locusts and Roses.

It is a very interesting fact that many woody plants are armed only while they are low, and their leaves can be reached by grazing animals. As soon as their twigs and branches are out of reach of the jaws of the beasts, they develop no thorns. The Holly is an example of this. The leaves which deck the crown of the high tree-trunks are entire and unarmed, while on the low shrubs the margin of the leaves is drawn out into sharp, spiny teeth.[1]

We may divide the weapons of the plant into two classes, the first of which includes the forms where the green tissue is protected by thorns and prickles developed on the green parts themselves; and the second, those where other portions of the plant are turned into arms to defend the unarmed green parts.

To the first class belong those leafless plants which have developed green tissue in their stems and twigs. It is true that the green branches of these plants are so stiff and hard that we should hardly think they would tempt animals to eat them. But "Hunger is a stern master," and experience shows that they are eaten. Not to be wholly at the mercy of such attacks, these leafless green-stemmed plants are often armed, especially by the ends of their green branches running out into spines, bristling against the assailant. Indeed, many of these plants are built up wholly of many-branched green thorns, which gives them a very singular appearance.

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[1] This is the subject of a little poem by Southey: —

"O Reader! hast thou ever stood to see
The Holly-tree?
The eye that contemplates it will perceive
Its glossy leaves;
Ordered by an Intelligence so wise
As might confound an atheist's sophistries.
Below, a circling fence, its leaves are seen
Wrinkled and keen;
No grazing cattle through their prickly round
Can reach to wound;
But, as they grow where nothing is to fear,
Smooth and unarmed their pointless leaves appear."

But the weapons formed on leaves are far more numerous than those with which green stems are provided. Sometimes sharp points proceed from the ends of the ribs and veins which make the leaf framework; sometimes they are formed of cells or groups of cells which originate in the epidermis of the leaf and stand out, now from the surface, now from the margin, like little daggers.

In the Southern Alps is found a species of grass (*Festuca alpestris*), growing in some places very abundantly. Its stiff leaves, which stand out in every direction, end in sharp points. This grass is more hated than any plant in the whole region, and the shepherds try to destroy it wherever it grows in any quantity. Grazing animals seeking other plants among the sods of *Festuca alpestris*, often prick themselves so severely that they come home from the pasture with their noses all running with blood. It is curious that when such grasses are easily uprooted the sheep themselves undertake their destruction.

Another bristly grass (*Nardus stricta*), when it grows on the heaths, is pulled out of the ground by the sheep, who seize the clods near the ground, uproot them, and again let them fall, so that the grass soon withers and dies. It is absurd to suppose that the flocks undertake with forethought this improvement of their pasture, but we can understand that they may pull up the bristly grass in order to enjoy the other sprouting plants beneath it, without the danger of wounding their mouths with the sharp points. . . .

Another form of leaf armed with spines is that belonging to the Thistles and their allied forms. Thistle leaves are often three, four, or five-divided, and variously incised and lobed. If the ends of all these divisions are metamorphosed into sharp points, little is left of the green tissue of the leaf; only a small green space remains in the centre, from which yellow and white thorns stand out on every side (Fig. 38).

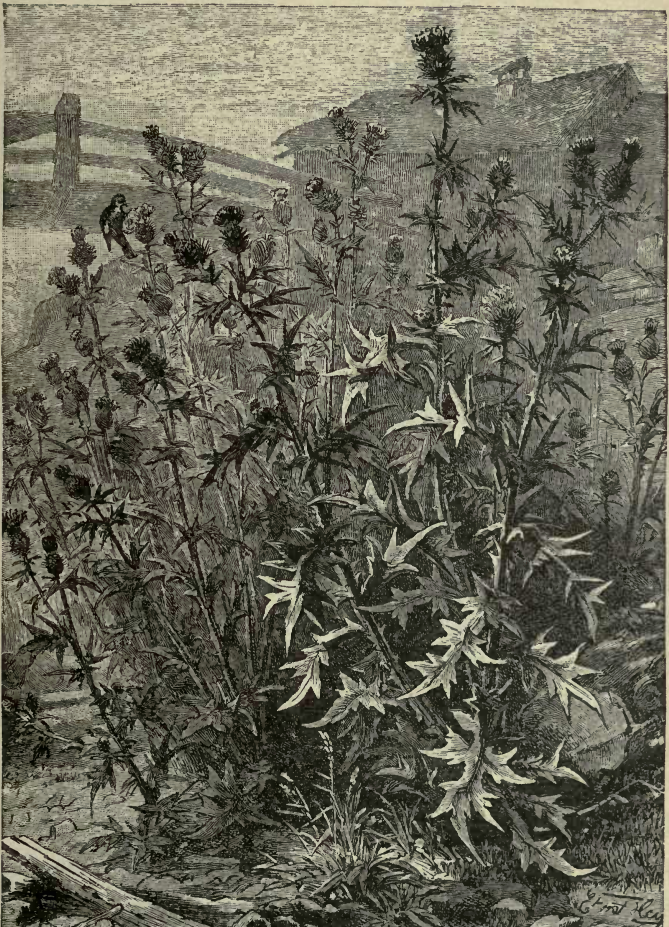

FIG. 38. GROUP OF THISTLES (Cirsium nemorale). ("Pflanzenleben.")

The prickly organs, which are not to be regarded as metamorphosed ribs, but which originate in the epidermis of the leaf, are sometimes many-celled, sometimes one-celled. One form of the one-celled prickles are barbs, formed of oblique conical cells, which stand out from the margin of the leaf. They end in a firm, hard point, which is usually somewhat hooked (Fig. 39, 7, 8). Leaves with their margins thickly covered with such barbs look like a saw under the microscope, and they are really able under some circumstances to act like a saw. If we stroke one of these barbed leaves very gently from the side towards which the barbs point, they do not cut into the opposing hand, but they also do not bend, but make a firm resistance. With increased pressure of the hand, the leaf itself is bent, but, as this is also well stiffened, the pressing hand experiences a resistance which would not be expected from so tender a leaf. If the hand is passed violently over the sharp margin, a bloody cut is made, in which the flinty teeth act precisely like the teeth of a fine saw. It is natural that grazing animals should shun these sharp leaves, and, in fact, they only eat them under great stress of hunger.

Another form of arms, which has its origin in the cells of the epidermis, consists of stiff hairs, or bristles, with thick, siliceous cell-walls, and sharp points. They arise generally in great numbers on the upper surface of the green leaves, and turn their points towards the side from which an attack is to be expected. In comparison with the barbs

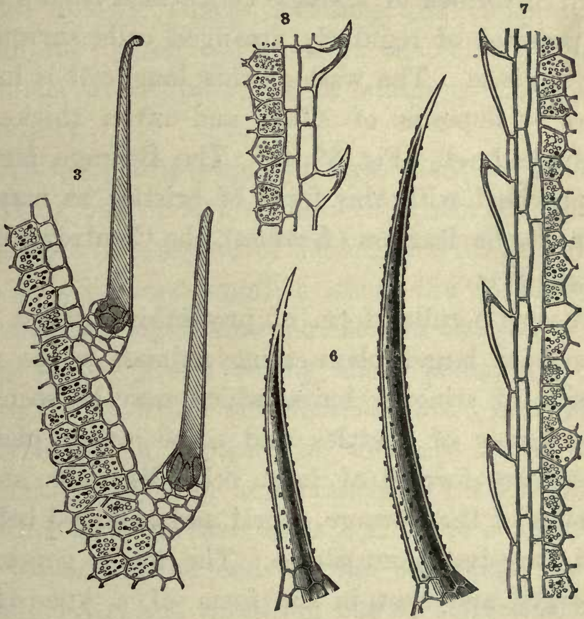

FIG. 39. WEAPONS OF PLANTS.

3. Section through a Leaf of Nettle (Urtica dioica), provided with Stinging Hairs. 6. Bristle of the Bugloss (Echium Italicum). 7. Margin of the Scabrous Leaf of a Sedge (Carex stricta). 8. Margin, beset with Barbs, of a Leaf of a Scabrous Grass (Festuca arundinacea). ("Pflanzenleben.")

they are large; for even the smallest is much larger than these, and the largest look like needles with their heads buried in the leaf. The bristle itself is formed of a single cell, which is on a sort of pedestal of regularly arranged cells, surrounding its base. The wall of this long cell is hardened by deposits of silica, and often thickened by little knots (Fig. 39, 6). The Borrage family is provided with this form of bristles, as may be seen in the Bugloss (*Echium*), the Comfrey (*Symphytum*), etc.

A very peculiar form of protection against the attacks of larger plant-eating animals is the possession of stinging hairs, which may be seen on the leaves of Nettles and some other plants. These are formed of large cells, like the sharp bristles of the Borrage, round and enlarged below, and long-drawn-out above. The top is generally enlarged and bent in the form of a knee (Fig. 39, 3). Here the cell-wall of the hair is very thin, so that the smallest pressure is able to break it. As the breaking follows an oblique line, a sharp point is made. If this brittle end of the hair is shattered by a pressure from above, the sharp point formed at the place of breaking presses into the opposing body; if this be soft and yielding, like the skin of man and beasts, the cell-contents are poured into the wound. If many stinging hairs side by side be pressed into the skin, there follows redness, swelling, and violent pain, from the poison contained in the cells. Grazing animals avoid plants with stinging hairs most carefully.

All the plants which we have mentioned belong to the group of forms where the green tissue itself possesses its weapons of defence. With this group we may contrast another where the defences are formed by neighboring members of the plant. To this second group belong those plants, the side branches of which are metamorphosed into woody thorns, which protect the unarmed leaves from attack. The stem and branches of these plants are not leafy to their ends. If there is any trace of leaves on the ends of the branches, they are small, scaly, and anything but an attractive food. The end of the woody branch is sharp and runs out into a pointed thorn. Here the work of defence is carried on by a division of labor. The green leaves can carry on their office undisturbed, under the protection of the thorns. An example of this may be seen in *Cytisus spinosus* (Fig. 40, 5).[1]

[1] A plant belonging to the same genus as the cultivated Laburnum.

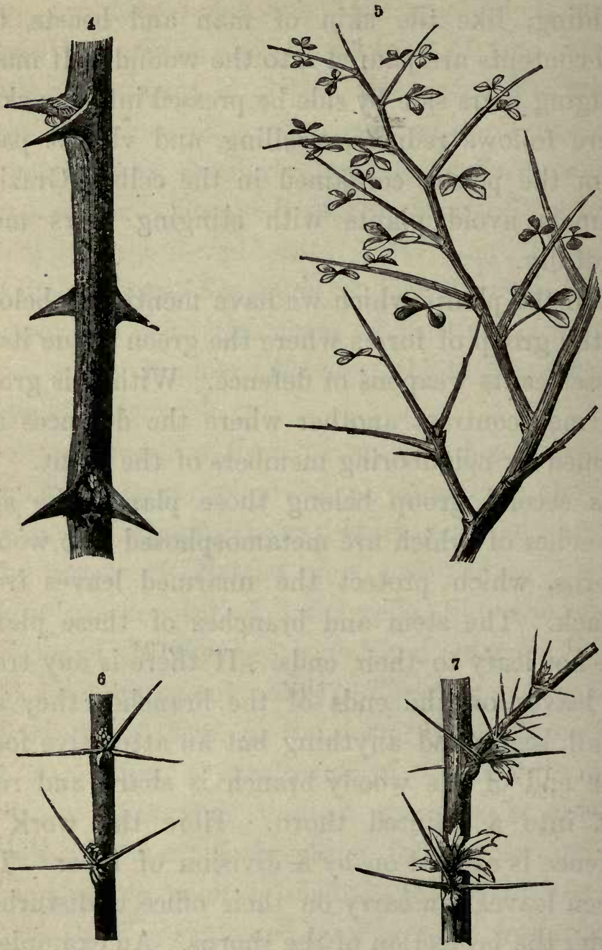

FIG. 40.

4. Robinia Pseudacacia in Spring. 5. Cytisus spinosus. 6, 7. Berberis vulgaris (Barberry) in Spring. ("Pflanzenleben.")

In the Barberry (*Berberis vulgaris*), there are two kinds of leaves, the foliage leaves and others which are not leaf-like at all, but are completely converted into sharp thorns. These are grouped in five to seven needle-like points at the base of the branch; higher up they are in groups of three (Fig. 40, 6, 7). Contemporary with these metamorphosed leaves, and close above them, arise short shoots, which are covered with ordinary green leaves. These shoots are terminated by buds, which develop in the next spring and form either flowers or a long shoot. The leaves of the rosette under this bud fall in the autumn; the thorns at the base remain behind, together with the winter buds, and stand out from the branch in three directions with their three-forked needles. In the following spring, when the terminal buds swell and expand, the tender young leaves are well protected from attack, during the time that they are overtopped by the thorns.

In the common Locust-Tree (*Robinia Pseudacacia*), the whole leaves are not metamorphosed into thorns, as in the Barberry, but only the stipules. These are not leaf-like, but are triangular, sharp, brown thorns. When the leaf falls in autumn these metamorphosed stipules remain behind, and last through the winter and even through the following summer. In the niche between these stipules, which make with each other an angle of 120°, nestles the bud, which unfolds in the following spring. As long as the tender young leaves remain in the niche between the thorny stipules (Fig. 40, 4), they are carefully shunned by animals; and only when they have grown beyond these thorny points, does this protection come to an end.

Most of these protective contrivances only protect the green leaf while it is in a young state. But it is just at this time that defence is most needful. If single leaves which project beyond the thorns are eaten, a part of the leaves remain, and the loss is not of much importance.

One extremely curious means of defence is not mentioned in the foregoing article. Certain plants secrete a nectar which is very attractive to black ants, who, therefore, take up their abode upon these plants, and constitute a sort of standing army, ready to resist furiously the onslaughts of leaf-cutting ants, of caterpillars, and even of the larger animals.

XII.

TRANSPIRATION.[1]

Transpiration means the evaporation of water from a plant. Let us imagine a plant which contains as much water as it is capable of holding, and is in contact with an available supply of water in the ground. Each cell contains its full amount of liquid, and, if no water is lost, no water will be absorbed by the plant. But now suppose that evaporation begins to take place from the cells which are in contact with the atmosphere. As the cell-walls allow liquids to pass freely, these cells immediately begin to draw on the water supply of their neighbors, and these, in turn, on the cells adjoining them, and so on, till throughout the whole plant there is an ascent of water to supply the place of what has been lost. Finally the call is made on the rootlets, and these promptly answer the demand by sucking in the needed liquid from the surrounding earth. Suppose this evaporation into the air to be continuous, and we have a constant stream of water flowing from the damp earth, through roots and rootlets, stem and branches, to the leaves. This is what actually does take place, and this stream is known as the transpiration current.

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[1] In compiling this article the editor has availed herself largely of the charming chapters on transpiration in "Pflanzenleben." The book contains many interesting suggestions on this subject, besides those which are given here.

But roots do not absorb water alone. The delicate hairs, — outgrowths of the skin, — which clothe thickly all their young parts, give out an acid which can dissolve the mineral matters in the soil. It is not certainly known what this acid is, but, whatever it may be, by a most beautiful arrangement it dissolves the food of the plant just where the root-hairs are present to absorb it. In this way roots are able to disintegrate the soil, and to absorb its mineral matters in weak solutions, which are carried all over the plant. They are brought in the way we have described into the cells communicating with the external air, where they are greatly concentrated by the escape of water, and are then ready to be converted into food. This is done by the action of carbonic acid gas, absorbed from the air. By means of this gas the raw mineral material brought from the ground is converted into organic matter, the food of plants and the food also of animals.

The path of the ascent of the crude sap is through the woody portions of the plant. The woody tissues of the roots carry the water from cell to cell to the fibrovascular bundles of the stem; it then rises through all the branches and twigs till it reaches the leaves. Each leaf has a woody framework, which divides again and again, till it makes a network of fibres, on which the green tissue (*parenchyma*) is supported. The most delicate fibrils of this woody framework are in close contact with the cells of the leaf which communicate with the outer air, and the water which has been brought hither from the roots escapes into the atmosphere.

We can see that it must be the wood which conducts the water, by looking at old trees, whose trunks are hollow and whose bark has also been destroyed around the base of the tree. This is especially striking in old olive trees, which often are not only hollow and destitute of bark, but are pierced and broken, so that the upper part of the tree looks as if it were mounted on stilts, and is only connected with the ground by woody tissue. Yet these olive trees are healthy, bring forth new branches every year, bloom, bear fruit, and supply their wants with nourishment, which could have come to them in no other way than through the wood of their scraped and hollow trunks.[1]

We may also prove that the crude sap rises through the woody tissues by *girdling* the stem of a tree; that is, by cutting off a ring of bark without injuring the wood.[2] This does not kill the tree, as may be seen in birch trees which have been girdled for the sake of the bark. But if the wood be cut in a similar ring the tree will soon die. Most of the water in a tree is carried up in the outermost layer of wood, just under the bark.

When the water reaches the leaves and is carried through the ribs and veins into the cells of the parenchyma of the leaf blade, it cannot escape into the air to any extent through the cell-walls of the epidermis, because their outer walls have been thickened and made waterproof. But the leaves are pierced by openings, connecting with the external air, through which water-vapor can escape and air can enter. These openings are called stomata (Fig. 41). They are formed by two cells, called guardian cells, with a narrow slit between them, which they have the power to open

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[1] "Pflanzenleben," Vol. I. p. 252.

[2] See "Lectures on the Physiology of Plants." J. von Sachs. Trans. by H. Marshall Ward. Oxford, 1887. p. 229.

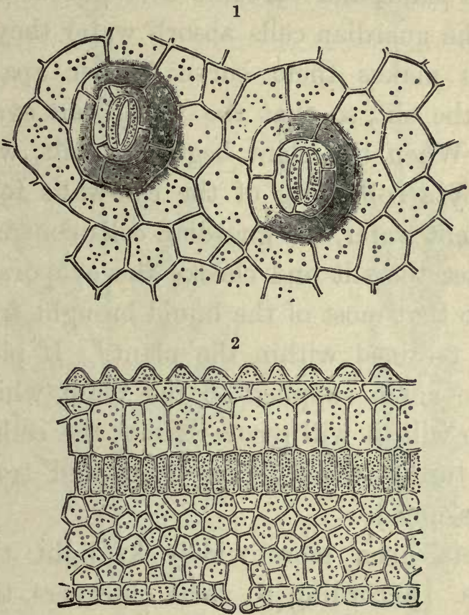

FIG. 41.
1. Stomata on a Leaf of Peperomia arifolia. 2. Cross-Section of the Same Leaf.
("Pflanzenleben.")

or to close. Both the cells are shaped like a half-moon, with the concave side towards the slit and the convex side joining the neighboring cells of the epidermis. Beneath the opening of each stoma is an air space, whence the air can pass into other cells of the plant. The stomata, therefore, are the breathing pores by means of which water is exhaled from the plant, and carbonic acid gas is inhaled. When the guardian cells absorb water they swell, and this makes them curve farther apart and widens the slit, so that the water can evaporate faster. When the plant begins to wilt, which is caused by a collapsing of the cell-walls for want of sufficient water, the guardian cells contract, and this closes the slit and checks the evaporation of water, so that most of the liquid brought from the roots is retained within the plant.[1] If plenty of water be again supplied to the plant which has begun to wilt, it will recover itself, the cells again become turgid, the stomata open, and transpiration is resumed.

Stomata open more widely in light than in darkness. According to some observers, they are always open in sunlight. This will explain the reason why stomata are generally more numerous on the under side of the leaf. Transpiration would go on too rapidly if they were exposed to the direct rays of the sun. Where the leaves are vertical instead of parallel with the ground, the stomata are on both sides of the leaf.

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[1] The mechanism is too complicated for further explanation here. See Sachs, "Physiology of Plants," p. 249.

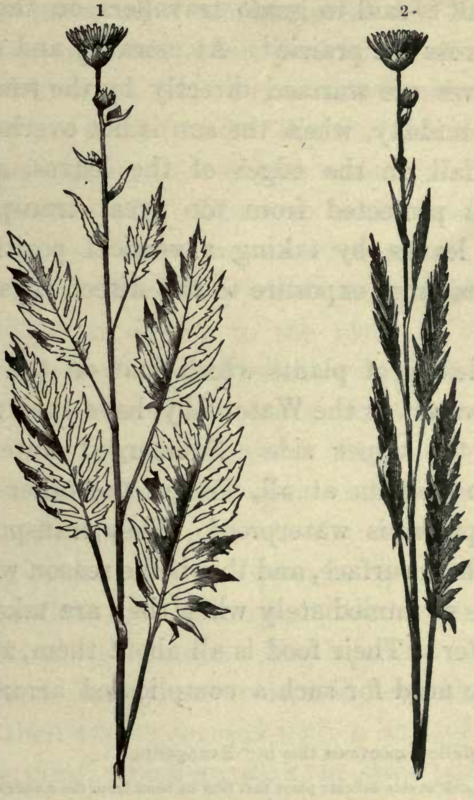

FIG. 42. COMPASS PLANT (Silphium laciniatum),
1. Seen from the East. 2. Seen from the South.

An excellent example of this is the Compass Plant (*Silphium laciniatum*, Fig. 42) of the Western prairies, which has its leaves placed vertically, with the edges pointing north and south, so that the plant is said to guide travellers on their journeys across the prairie.[1] At morning and evening the leaves are warmed directly by the sun's rays, but at midday, when the sun is hot overhead, the beams fall on the edges of the leaves, and the plant is protected from too great transpiration. Young leaves, by taking a vertical position, are protected from exposure to the direct rays of the sun.[2]

The leaves of plants which float on the surface of the water, as the Water Lily, have their stomata all on the upper side. Submerged water-plants have no stomata at all, nor are the outer cells of their epidermis waterproof. They transpire from their whole surface, and this is the reason why they collapse so immediately when they are taken from the water. Their food is all about them, and they have no need for such a complicated arrangement for pumping it up from the roots as land-plants possess.

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[1] Longfellow mentions this in "Evangeline":

> "Look at this delicate plant that lifts its head from the meadow,
> See how its leaves all point to the north, as true as the magnet;
> It is the compass flower, that the finger of God has suspended
> Here on its fragile stalk to direct the traveller's journey
> Over the sea-like, pathless, limitless waste of the desert."

He is in error, however, in calling the plant delicate.

[2] See VIII. "Young and Old Leaves," p. 84.

The stomata are of course a great deal too small to be seen without a microscope, but there is a way in which we can tell on which side of any leaf they are to be found. Dip the leaf in water, and, after holding it there for some time, take it out and shake it. Wherever a film of water covers the leaf, there are no stomata; but where the leaf is dry, there they will be sure to be found.[1] It would be an injury to the plant to have its breathing pores clogged with water. Therefore the surface where the stomata are is protected in various ways from the wet. Many leaves have what we call "bloom" upon them. This is a waxy coating which prevents the rainwater from adhering to the leaves. It can be observed on the leaves of Cabbage, Nasturtium, Castor Oil Plant, Begonias, and Primroses. The beautiful Gold and Silver Ferns in our conservatories have the lower side of their leaves covered with a sort of yellow or white meal, which answers the same purpose.

Another mode of protection is through the help of hairs. A countless number of leaves of our common plants are covered with fine hairs, and these are more frequent on the lower sides of the leaves. If we dip these leaves in water, the wet collects in the form of drops, which roll off when the leaf is shaken and leave no moisture behind. It might be thought that the under side of a leaf would be protected by its position from rain, but if we turn over a leaf on a dewy morning, we shall find that the water is as much on its under as its upper side. We forget, when we speak of the falling of the dew, that this is only a figure of speech, — that the dew is really condensed just as much on the lower as on the upper side of a leaf.

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[1] "Pflanzenleben," Vol. I. p. 267.

These waxy coverings to the leaves and their garments of hair prevent excessive evaporation, and are often also a defence against the attacks of animals.

Another means of defence is the occurring of numberless little projections all over the surface of the leaf. When the falling drops of water roll over such a surface, they cannot dislodge the air which fills the depressions. As the stomata are always in these pits, they are kept dry, and are not wet even if the whole plant is immersed in water. This means of protection is common with plants growing in places where they are liable to be immersed for weeks together, as with some

Grasses (*Glyceria aquatica, Phalaris arundinacea*), Sedges (*Carex stricta*), and Knot-weeds (*Polygonum amphibium*). It is a pretty sight to see one of these leaves held under water. The whole under surface shines like quicksilver, and however we may shake and turn the leaf, we cannot dislodge its covering of air. When we take it out of the water this side of the leaf is quite dry, while the other is wet. Stomata are also found on stems, but they are not so numerous as on leaves.

Some kinds of trees may have a great effect in transferring water from the soil to the atmosphere. The Eucalyptus tree is the most useful for this purpose, and is often planted in order to drain marshy places.

Louise, J. Quackenbush

XIII.

USES OF FORESTS AND OTHER PLANT COVER'NG OF THE EARTH.

By N. S. Shaler.

The greater part of the land surface of the earth is thickly covered with growing plants. Where the rainfall is sufficient and where the region is exempt from wide-spread fires, such as sweep over the prairies of the Mississippi Valley, we always find a growth of forest trees. Where the rainfall is scanty, or where these annual conflagrations occur, the forests are replaced by grasses, or other low-growing plants, which may maintain their roots in a living state through the winter, but have no permanent growth above the level of the soil. Generally speaking, only those regions where the rainfall is less than about ten inches a year are without plant covering of any kind, and this area is but a small part of the surface of the earth.

The influence of this coating of plants on the conditions of the earth is very important in many ways. We will consider some of its simpler effects, paying particular attention to the influences which most concern man.

The most immediate effect produced by forests is the improvement of the soil into which their roots penetrate. Wherever trees succeed in finding a foothold upon the surface of the earth, they proceed at once to make and to preserve a coating of soil, which in the end may become fit for cultivation. The roots penetrate downward into the crevices of the rock, starting as slender filaments which, growing in size, wedge the stones apart and thus make the beginnings of a soil. Into every cranny of the disrupted stone, yet other roots find their way and repeat the process of breaking. In this way in the subsoil, the rock is fractured into bits, becomes subjected to the dissolving action of the soil water, and so affords food for plants. As long as the rock remains in the condition of a solid mass, it can yield but little plant-food. In that condition there is only a small amount of surface for the water to work upon. If we break a cubic foot of that rock into bits a cubic inch in size, we multiply the surface exposed to solution twelve-fold. If these bits are in turn divided into cubes the twelfth of an inch on a side, we again multiply the surface exposed to the water by an equal amount; and when we come down to the fine grains of mud which in time are made from the larger fragments, we find that the surface of the rock from which the waters may dissolve plant-food is increased many thousand fold by the process of division. The root-hairs, also, secrete an acid, capable of dissolving mineral substances with which they are in contact, and this acid fluid aids them to decompose the particles of stone. In this way the rootlets of the plants serve in part to create from the solid rocks the soil that gives them support.[1]

Not only do the trees help to make the soil upon which they dwell, but they also preserve it from destruction. If the reader will notice any tilled field in a time of heavy rain, he will perceive that the soil is rapidly borne away in the form of mud to the rivers and thence to the sea. If he will observe such a piece of ground after a heavy rain, he will often notice flat pieces of stone or potsherds resting on top of little columns of soil. From this he may draw the conclusion that during the rain the soil has washed away to a depth equal to the height of the column on which the flat fragments rest. In fact, they have protected the earth immediately beneath them from the destruction which the rain brings about. It is a well-known fact that in all countries where the soil has long been tilled, it constantly diminishes in depth and, unless great care is taken, in a few centuries it passes away into the streams, only remaining where the surface is very level. Thus in Italy and in many of the countries which have long been tilled, the soils on the steeper slopes which once were fertile have now so far disappeared that many extensive districts are given over to sterility.[1]

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[1] This influence of plants on their mineral substratum is clearly evident where Lichens and Mosses attach themselves to the free surfaces of rocks, *e.g.*, on high mountains. The solid crystalline surface of the stone becomes gradually converted, by the activity of the roots of these plants, into a friable, crumbling, loose substance. This decay continually penetrates deeper into the stone, and so affords a substratum in which even the stronger roots of larger plants can then obtain a hold. "Lectures on the Physiology of Plants." Sachs.

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[1] In May, 1888, a new forest law went into effect in Italy, by which the government pledged itself to pay three-fifths of the cost of reforestation of the mountain districts, the rest of the expense to be met by the owners. In case the owners do not consent to the plan prepared by the Department of Agriculture, the government is to be at liberty to take the land with proper compensation and perform the work alone. The estimated cost of the plan proposed is $12,000,000. Such enormous expense in the near future can be spared to America at a very small cost of present money and labor. If we do not soon take some more effective means than at present to preserve our forests our descendants will have to follow the example of Italy and spend millions, where we might have accomplished better results with thousands.

Forests serve not only to prevent the wasting of the soil under the pelting influence of the rain but they also greatly restrain the action of the rivers, even the largest. Thus the Mississippi River and other similar great streams are restrained in the destruction they would otherwise bring to the alluvial plains on either side of their current by the constant growth of trees which line the banks. Willows, Poplars, and certain other water-loving plants thrive along the banks of the stream, send their roots downward beneath the surface occupied by the flood-waters and so make a strong net-work which resists the cutting action of the river and keeps the stream within narrow bounds. Even in our brooks where they flow through virgin forests the falling trees and other drift-wood make frequent dams across the path of the waters, and here the soil washed from the highlands is retained, making little patches of earth.

Forests also act to prevent floods. If the rain falls on an unforested country the water flows quickly over the bare surface to the brooks and thence to the larger rivers on its way to the sea. In such a region the rain goes away to the ocean as it does from our house roofs or paved streets. When, however, the rain falls upon the forests, the water enters into a thick spongy layer, composed of partly decayed leaves together with trunks and branches which are constantly dropping from the trees upon the surface of the earth. Through this sponge the water moves but slowly on its way to the streams, and when it is actually in the brooks its progress downward is retarded by numerous dams made as we have just described by fallen timber and drift-wood. The result is that instead of pouring swiftly to the sea, the flood-waters may slowly creep away, requiring weeks in place of hours for their discharge to the greater rivers.

There is another effect which forests have upon the soil, an effect which is not exercised by any plants less in size than our trees. The strong roots of trees, penetrating far down into the crevices of the rocks and into the subsoil, draw upward above the surface and build into their trunks the solid matter which we find in the ash remaining after the wood is completely burned. This valuable nutritive matter drawn from the depths is returned to the earth when leaves and branches decay, and is thus stored in the upper part of the soil, and becomes accessible to the growing crops. Furthermore the trees in their growth gather, as is the case with all plants, a large part of their substance from the air. All the material which goes into the air when we burn wood came from the atmosphere during the growth of the plant. When the tree dies, or when its leaves and branches fall in the perennial death of its parts which attends the growth of the whole plant, this carbon drawn from the atmosphere is more or less built into the soil, giving it the blackish look which is always found in fields recently won from woodlands. This mixture of decayed vegetable matter serves in several important ways to make the soil fruitful. The farmer has to imitate the natural process which goes on in the forest by ploughing in clover, buckwheat, or other crops in order to introduce the vegetable matter into the soil and so maintain its fertility.

The utility of forests to man, though best exhibited in the processes by which they make, save, and enrich the soil, is shown in many ways. From the forests we derive the construction timber, which constitutes a large part of all houses, and of itself is sufficient for the greater part of the dwellings inhabited by man; without this supply hardly one of our arts could be maintained. Even in our large cities, where the outer walls are of masonry, the greater part of the structure is composed of wood. So, too, timber is necessary for the construction of our agricultural machinery, of the greater part of our ships, and of a host of other structures which are essential to the well-being of man. In the present state of our arts, we could more easily give up all the other resources drawn from the earth, except perhaps iron, than forego the use of wood from our civilization.

Although mineral coal has, in the more civilized parts of the world, to a great extent taken the place of wood for heating purposes, probably three-fourths of the domestic hearths in the world are supplied from the forests. In time it is to be hoped that the use of stone coal will become yet more extensive, for it will diminish the tax which is made upon the woods, and so spare them for more necessary uses.

Among the uses of the forests we must include the shelter which they afford to human beings, and to the cattle of our farms. Where the country is untimbered, the winds, having a free sweep over the surface of the earth, move in times of storm more furiously than in the forests, where the trees afford a most important shelter. In the prairie districts of the upper Mississippi, it has been found necessary to plant trees about the homesteads in order to make them reasonably habitable during the blizzards and to shelter the stock.

The character of the forests varies greatly in different parts of the world. The noblest woods of the earth are probably those of North America. The district of the Appalachians from Northern New York to Alabama, though much harmed by the woodsman's axe and more by fires, still presents the finest areas of broad-leaved trees in the world. Individual members of related kinds in other countries may be nobler specimens of growth, but nowhere else are the woods so continuous and so luxuriant over a wide-spread surface. In the western parts of the continent, near the Pacific coast, the narrow-leaved coniferous trees take on a lofty growth. The great Sequoias or Redwoods of California are probably to be ranked as the noblest plants in the world, being only approached in size by some of the great trees of Australia, which do not, however, attain the same majesty as those of the Pacific coast.

Where trees grow in the close-set order of the forest they attain a greater height than in the open ground. For great forests have been developed in the endeavor of each tree to overtop its neighbors and obtain a measure of the sunshine, without access to which the plant cannot do its best work. To develop a forest of very tall trees demands long ages. If we cut a wood away and permit the trees to grow again, they will develop with much shorter stems than the parent wood. Only slowly does the forest climb again to its primeval elevation. Hence it comes about that the forests of the New World are so much higher than those of the Old. In Europe there are hardly any woods, at most but scant patches, which have escaped the axe. Almost all the timber is of the second growth.

The close relation of forests to the needs of man make it essential that in any country, which is to be kept in the best condition for human occupation, a large share of its woodlands should be spared destruction. When civilized men first came to this country, they found all the regions to which they had access in the state of dense woods. It was a difficult matter to clear away these forests in order to reduce the soil to the uses of the plough. Thus the farmers have got into the habit of looking upon the woods as enemies to be driven away. The result of this is that the destruction of the forests has proceeded with great rapidity; indeed, with a recklessness which jeopardizes the interests of many communities. Thus, in the valley of the Ohio, the rapid destruction of the woods now necessitates the bringing of timber for building purposes from great distances.

In almost all countries a portion of the surface seems marked by nature as the fit place for the growth of woods. The steep mountain slopes or the rocky parts of the lower hills which are not by their position well suited to the growth of tillage crops are generally admirable places for forest uses. Trees will not only grow but flourish exceedingly on slopes so steep or so stony that they are unfit for cultivation. A proper economy dictates that all such regions should be left in their original forest condition, or if they have been recklessly cleared away, that trees should be replanted upon them.

Last of all, we may note the elements of beauty which are afforded by our woods. None accustomed to dwell near pine trees or within accessible distances of the primeval forest has any idea how important are these elements in the landscape. If he will dwell awhile on the prairies, where trees are found only near the larger streams, and there, indeed, in scanty growth, he will soon come to recognize that the beauty of the woods is in a way essential to him, and he thus can measure how great is his enjoyment in the sight of forests.

The woods not only afford a noble life in their own trees, but they supply a place for the protection of a host of beautiful animals. A large number of our birds are not found in countries where trees do not abound. Our squirrels and various other mammals depend upon the forests for their maintenance. Thus the woods maintain a wider range of animals than can possibly exist in countries where there are no forests.

XIV.

PARASITIC PLANTS.

TRUE parasites are plants which attach themselves to others and feed, either wholly or in part, upon stolen juices.

Bacteria are microscopic parasites which multiply with marvellous rapidity, building up cell after cell at the expense of the organism in which they live. Our contagious diseases are ascribed to the presence of bacteria in the blood.

Many fungi and lichens are parasitic, drawing their nourishment from the plants on which they grow. The gardener scrapes his fruit trees, that the fungi on the bark may not extract the food which should all be used to nourish blossom and fruit.

We will now consider only the parasites which are found among the higher plants.

Parasitic plants may be either colored or green. The former class have no green leaves. They are therefore unable to digest their own food, and must take it ready-made from others. The Dodder is an example of this kind of parasite. It has no roots or leaves, but lives by sending suckers into its foster-plant, or *host-plant*, and absorbing its sap.

Green parasites are able to elaborate their own food, and may therefore be either wholly or partially parasitic. An example of a parasite which has no connection with the ground is the English Mistletoe. As it has green leaves it can take its raw material from the host-plant and make it into food, so that it probably lives both on the crude sap and food materials of the plant on which it grows.

Partially parasitic plants live apparently in the usual way, by the fruits of their own labor, and steal secretly from the prepared stores of others. Our Gerardias are of this class. Their roots make an underground connection with the roots of other plants and draw food from them.

We will now examine some examples of these classes a little more in detail.

The Dodder is one of our most common parasites. Its yellow, thread-like stems wind about low bushes and bear clusters of white flowers, but they do not possess any trace of leaves. This plant is not especially troublesome with us, but its near relatives in Europe attack the Flax, Clover, and Hop fields, and are much dreaded. The Dodder which infests the Hop is called in Germany "Devil's thread" (Teufelszwirn). The germination of our common species, *Cuscuta Gronovii* is similar, excepting that the embryo is more coiled in the seed.

"Among the species of Cuscuta, certain European ones have obtained a specially bad reputation, because they are so troublesome in agriculture. The most notorious of these is *Cuscuta trifolii*, called Clover-silk (Kleeseide), whose advent in the clover fields is so displeasing to the farmer, and whose destruction gives him so much trouble. Another unwelcome guest is *Cuscuta epilinum*, which winds about the stem of the Flax and hinders it in its growth, and a third, *Cuscuta Europæa* (Fig. 43), often destroys the Hop. The last is the most widely distributed of all the species of Cuscuta, and is found from England, through Central Asia, to Japan, and southward as far as Algeria. It is not only parasitic on the Hop, but also on the Elder and many other shrubs, and it especially prefers the Nettle.

"The seeds of this, as well as almost all the species of Cuscuta, germinate on damp earth, on leaf-mould, or upon the decayed bark of old tree-trunks. The embryo, which lies embedded in the albumen of the one-celled seed, is in the form of a thread and rolled spirally. It forms a circle of a single turn or a turn and a half, and is thickened at one end in the shape of a club. There is not a trace of cotyledons in the true species of Cuscuta.

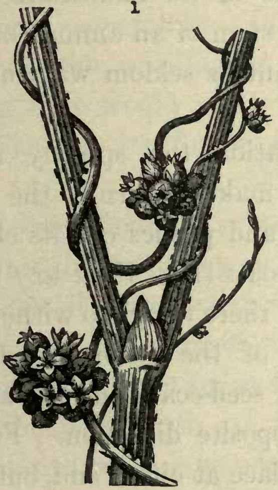

FIG. 43. CUSCUTA EUROPÆA, PARASITIC ON THE HOP. (Natural Size.)
("Pflanzenleben.")

"The seed lies on the ground in the open air all through the winter, and germinates very late in the following spring, at least a month later than the other seeds which have reached the same spot of ground. This fact is of great importance to the parasite, because when it germinates perennial plants have already sent up stems from their underground rootstocks. If the seed had germinated early in spring, it would not easily have found a support in its immediate neighborhood, while later, the stem of an annual, or the sprout of a perennial plant, is seldom wanting about which it can wind.

"In germination the spirally rolled embryo stretches itself, makes a turn to the left, takes the form of a bow, and pushes out its club-shaped end from the seed-coats (Fig. 45, *a* to *f*). This enters the ground and there clings to withered leaves, etc. The small end of the filiform embryo, still surrounded by the seed-coats and the albumen, raises itself in the opposite direction. Further growth does not take place at either end, but in the middle of the thread, and is very rapid, so that on the fifth day the whole seedling has lengthened itself fourfold. On the third day of germination the seed-coats, covering the upper end, are thrown off, and the apex of the seedling is exposed. The store of food provided for the young plant for its journey is now used up, and it is thrown entirely on its own resources. As it has no trace of breathing-pores it cannot supply itself with nourishment from the air, nor can it absorb water with its club-shaped end. It grows without doubt at the expense of the materials which are contained in this thickened end, which then begins to shrink and soon dies away, while the upper end of the thread lengthens perceptibly. In the meantime, if this part of the seedling comes in contact with anything that would serve it as a support, it embraces it, and its future is generally assured.

"If the seedling finds no support, it falls upon the ground after the withering of the club-shaped end; in this act it often strikes a neighboring plant, and twines itself immediately about it. If, however, a support is wanting and the young seedling lies on the bare earth, its future growth is stopped. It keeps alive a wonderfully long time, and may remain unchanged for four or five weeks, waiting for rescue. Often the relief comes when another plant germinates at its sides, or a growing sprout pushes up beside it and touches the Cuscuta. In this case it seizes the friendly cable and twines about it. If no support is forthcoming, the seedling dies. It is worthy of notice that these threads which develop suckers when they are fastened to a living plant, are unable to develop any such absorbing organs in the damp earth.

"If the filiform Cuscuta seedling grasps a support, either while it still possesses its club-shaped lower end, or after this has withered away, it makes two or three turns about its prop, and then raises again its growing apex, which circles around like the hand of a clock. By this movement, which makes the impression on the beholder that the plant is groping for a support, the thread comes in contact with new stalks, branches, and leaf-stems of other plants, seizes them, and makes again two or three close turns about the new support. In this way the growing apex of the young plant dispenses as soon as possible with dead supports, and gives the preference in a remarkable manner to the living portions of the plants on which it has fastened.

"When the Cuscuta has embraced its support, the thread swells somewhat and forms suckers, which are generally near together in a row of three, four, or five (Fig. 43).

"Such a piece of stem, furnished with suckers, resembles a little worm, which creeps around the supporting stem. At first these suckers are exactly like forming roots and appear smooth on the upper surface, but they soon assume a finely granular appearance, by the walls of the epidermal cells arching outward. By the help of these papillæ, and especially by means of a juice which they secrete, the suckers fasten themselves to their support. If the suckers have attached themselves to a dead body they flatten themselves out upon it, and make a kind of disk, which undergoes no further development and serves only as an organ of attachment; but if the prop is a living plant, a bundle of cells presses forth from the middle of the sucker, and presses into the living tissue of the assailed plant (Fig. 44). This entrance is effected with great violence. The bundle of cells breaks through the firmly united cells of the epidermis

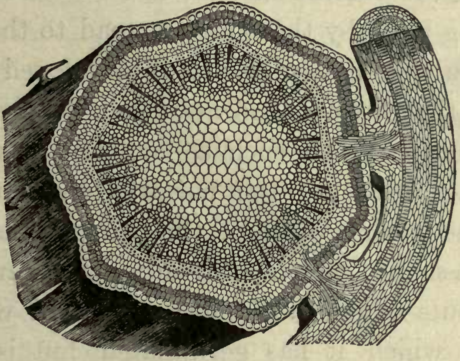

FIG. 44. CROSS SECTION OF CUSCUTA, PARASITIC ON THE HOP.
(" Pflanzenleben.")

of the host-plant, often through a thick rind, and penetrates as far even as the woody tissue. Once having entered the host-plant, the cells, until now united in a bundle, isolate themselves, move apart, force themselves singly into the cells of the host, and become now active absorbing cells. They draw out the organic substances of the foster-plant and bring them by the shortest road to the fibres, which, in the meantime, have developed in the stem of the Cuscuta, and are grouped in a narrow circle there. When such a connection is finally established, between the parasite and the host-plant, the lower portion of the parasite dies away. The club-shaped end has already disappeared, and the Cuscuta is now no longer connected with the earth in which it has germinated, but is rooted only to the host-plant, by means of the suckers."[1]

Another kind of parasite which is without green coloring matter, and therefore unable to digest its own food, is Beech-drops (*Epiphegus Virginiana*). This is an example of a root-parasite. It belongs to a family (*Orobanchaceæ*) consisting of brownish or yellowish plants, with scales instead of leaves, which are all root-parasites. The *Epiphegus* lives on the roots of the Beech. It has a seed without cotyledons or distinction of root and stem. The seedling is a thread which grows downwards till it comes in contact with a root on which it fastens. It is unable to take its food from the soil. Fig. 45, *g* to *m*, represents the seedling of a Broom-rape (*Orobanche epithymum*), a European member of this family. When the seedling fastens on the root it thickens and becomes knotty and warty. In England there are eight species of Broom-rapes, which grow on the roots of Broom, Clover, Hemp, etc. They injure the clover fields by stealing the nourishment from the roots of the plants.

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[1] This account of the germination of Dodder is quoted from "Pflanzenleben," p. 159.

There are a great many of these brown, yellow, or flesh-colored parasites in tropical countries. The largest flower in the world is said to belong to a parasitic plant, *Rafflesia Arnoldi.* It is a yard across. It lives in Sumatra on the roots of a kind of vine.

The English Mistletoe is a good example of a wholly parasitic plant. The bright white berries are very attractive to birds, who eat them freely. The hard seeds are not digested by the birds and fall on the trees, where they soon germinate if the situation suits them. They are especially fond of the Black Poplar (*Populus nigra*). The occurrence

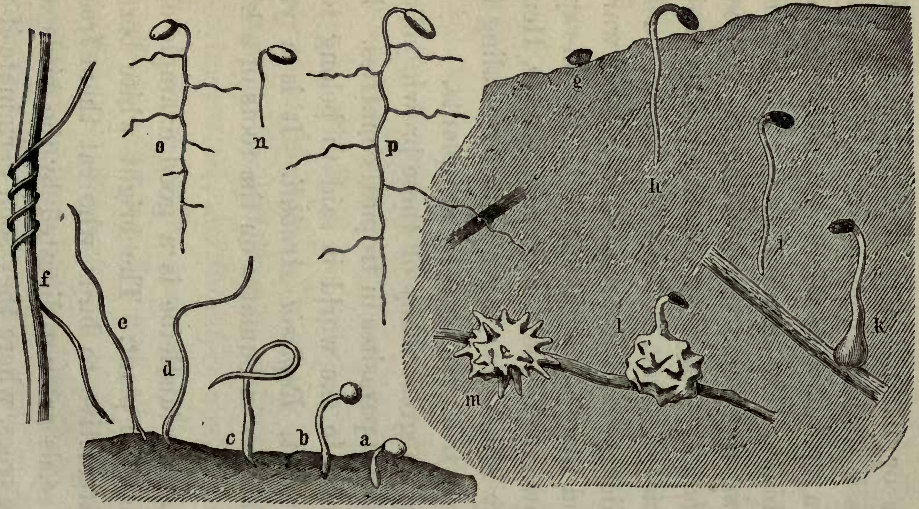

FIG. 45. SEEDLINGS OF PARASITES.

a to *f*. Dodder (Cuscuta Europæa). *g* to *m*. Broom-Rape (Orobanche epithymum). *n* to *p*. Cow-Wheat (Melampyrum silvaticum). ("Pflanzenleben.")

of the Mistletoe on the Oak is extremely rare, so that it is said to have been regarded by the Druids as a sacred event, and to have formed part of their religious rites.

The seedling has two cotyledons which are imbedded in albumen. In germination the portion of the caulicle under the cotyledons elongates, and grows towards the bark of the tree, exactly as the caulicle of an ordinary seedling grows towards the ground. When it reaches the bark it makes a disk, and, out of the middle of this disk, a fine root-fibre enters the bark of the tree, and penetrates it as far as the wood.

The following year the tree forms a new ring of wood, which surrounds the root-fibre of the Mistletoe and pushes out the bark before it. The root does not grow into the wood, but the wood grows around the root, so that it would in course of time be completely buried up. To prevent this, a zone of cells is formed around the base of the Mistletoe root, which keeps pace in its growth with the ring of wood, and apparently continues outward the growth of the root. This growing zone of cells sends out side branches which run parallel with the axis of the branch and incorporate themselves with the bark. These branches develop new roots, which grow perpendicular to the axis of the branch, and become gradually surrounded with wood, exactly as happened to the first root. As this is continued every year, the branch becomes pierced with many roots, surrounded with yearly rings of wood, which decrease in number in proportion as the distance from the original root increases (Fig. 46, 1).

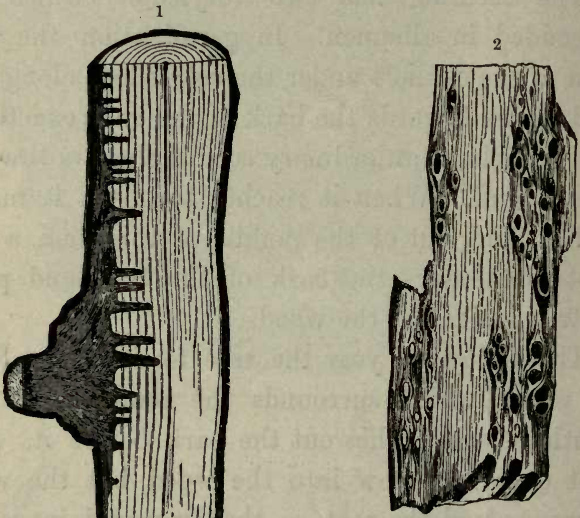

FIG. 46.

1. Mistletoe (Viscum album), Parasitic on the Branch of a Tree. Cross-Section through Branch and Parasite. 2. Piece of Fir Wood, pierced by the Root-Fibres of the Mistletoe. ("Pflanzenleben.")

As the Mistletoe has green leaves, it can digest

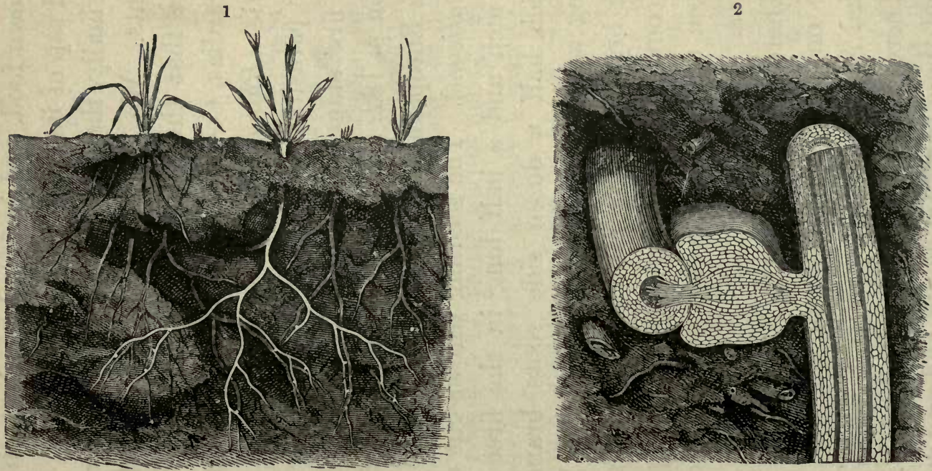

FIG. 47. THESIUM ALPINUM, A ROOT-PARASITE.

I. Root with Suckers. 2. Cross-Section of a Piece of Root with Suckers. (Magnified.) ("Pflanzenleben.")

its own food, and is not dependent on the organized sap of its host-plant.

Finally, there are many partially parasitic green plants. We should not know from their appearance that they were living on stolen stores. The Gerardias, Cow-wheat (*Melampyrum*), and Yellow-rattle (*Rhinanthus*) are examples of this class. The parasitic habit is not visible in these plants in the first stage of their development. Fig. 45, *n* to *p*, on p. 182, shows the germination of a seedling of a European species of Cow-wheat (*Melampyrum sylvaticum*). The seedling throws out a main root an inch and a half long in the first week, from which half a dozen side roots branch, without being attached to any other plant. When these side branches have grown long enough to come in contact with the roots of other plants, they fasten upon them, develop suckers, and steal their juices.

There are other plants, like Indian Pipe, which live on decaying matter in the soil. These are called *Saprophytes*.

There is a great deal still to be investigated about these parasitic plants, and any good observer could record many interesting facts.

XV.

INSECTIVOROUS PLANTS.[1]

MARY TREAT.

THERE are many seemingly strange things in nature, but perhaps none more remarkable than the fact that some plants kill and consume small animals, thus reversing the order of nature's laws, or as we have been taught to look upon her laws.

The most common of these plants are the Sundews or *Droseras.* There is scarcely a swamp in any part of our country, either North or South, which does not contain one or more species of these interesting plants. The leaves of the different species are covered with hair-like glands or, more properly, tentacles surmounted with glands, which exude a clear, viscid fluid that glistens in the sunshine like tiny drops of dew, from which the plants take the name of Sundew.

The Round-leaved Sundew (*Drosera rotundifolia*) is more often found in the Northern States than either of the other species. Its leaves are arranged in a rosette and lie flat on the ground, or on the moss among which they often grow. Some of these little plants have a rosy, pink hue, and look wonderfully attractive as they sparkle in the sunshine. No doubt the glistening brightness lures many little thirsty insects to the cool-looking, dewy leaves. But no sooner does one touch a leaf than it finds itself held by the deceptive, sticky fluid, and the more it struggles to become free, the more it is entangled. As it stretches and reaches out to get away, it only comes more and more in contact with other bristling filaments, until finally it has no power to move, and the remaining filaments which it did not reach are all soon curved and bent toward the poor captive, which is quickly bathed in the slimy secretion, and dies within ten or twenty minutes after it is caught. This secretion dissolves or digests all the soft parts of the little victim which are absorbed by the plant, while the shelly, indigestible parts remain on the leaf until it becomes dry, when the particles are blown off. As soon as the insect is disposed of, the tentacles resume their erect position and the glands again begin to secrete the sticky dew in readiness for more prey.

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[1] The first experiments on the digestion of animal substances by plants were made by Kanby on Dionæa (1865) and by Mrs. Treat on Drosera (1871). In 1875, Darwin published "Insectivorous Plants."

The illustration of the Sundew (Fig. 48) represents two leaves magnified about three times. One leaf has all the tentacles in the normal position, while the other has a part bent over some small creature.

Why *Drosera* consumes insects is easier asked than answered. The plants live in water, or in very moist places, where the roots can imbibe or drink so as to supply the viscid secretion that it may capture its prey. And this Round-leaved Sundew grows mostly among sphagnum moss where it is almost impossible for it to obtain the usual plant-food or nitrogenous matter except as it gets

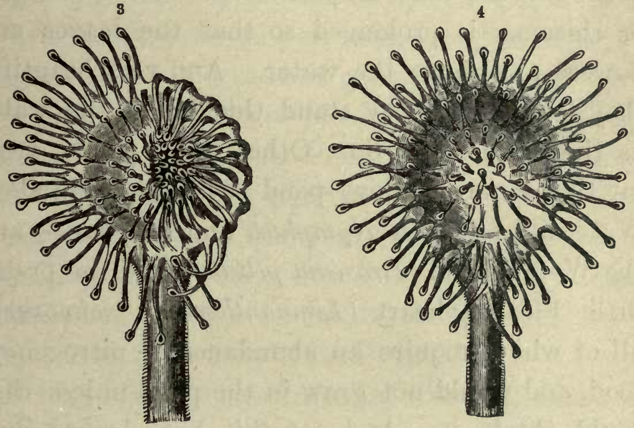

FIG. 48. LEAVES OF SUNDEW (Drosera). (Magnified).

it from the insects which it entraps and consumes. But this cannot be said of the Long-leaved Sundew (*D. longifolia*) which grows in black, muddy ponds and bogs.

The latter sometimes grows in water from ten to twelve inches in depth, and the roots are imbedded in the black mud beneath. But the caudex, or rhizoma, is prolonged so that the leaves and flowers are above the water. And very beautiful they look when they stand thickly on the water as they sometimes do. Other water-plants grow in the same shallow pond with this Sundew. Water-lilies — both *Nymphæa* and *Nuphar* — and the Water-shield (*Brasenia peltata*), and the pretty little Floating-heart (*Limnanthemum lacunosum*), all of which require an abundance of nitrogenous food, and would not grow in the pond unless they could obtain it. And yet this Long-leaved Sundew which grows with them is a most expert fly-catcher, and, although it cannot be said that it is necessary for this plant to capture insects for food, it entraps them all the same. Sometimes large flies and small butterflies and moths are caught and the leaves roll entirely around them. They roll from the apex to the base, holding their prey until all the soft parts are absorbed, when they unfold and let the wings and legs and other indigestible portions fall off.

But the most beautiful and curious species is the Thread-leaved Sundew (*D. filiformis*). Its leaves are erect, and from six to twelve inches in length — simply thread-like and covered with tentacles and glands from base to tip. It grows from a little bulb usually in pure white sand in springy places so that the sand is gently overflowed with water. I do not know of any other plant more attractive than this. It looks so fresh and clean and sparkling in the pure sand and water. The viscid dew makes it look as if covered with little gems of various hues. The flower-scape is a trifle longer than the leaves, and bears charming rose-purple flowers an inch or more across.

Hosts of insects are lured by the brightness of the plants, which they no sooner touch than they are held captive. And here we can see that it looks as if the plants needed them for food, growing as they do in sand and water. This species kills and consumes much larger insects than either of the others. Great dragon-flies, butterflies, and moths, as well as two-winged flies, are caught and killed.

The long leaves, standing erect and thickly together, hold and bind the victims much more effectually than the other species. The larger the insect the more leaves it reaches and draws around itself, until it is soon bathed in the sticky secretion which closes the trachea or air-tubes, when it speedily dies.

Like the other species, it absorbs the nutritious parts and lets the rest fall at the base of the plant, where we can find a good share of the remains of the prey it has slaughtered, especially of the larger insects. Probably this *débris* is something of a fertilizer and helps to nourish the plant.

I have observed two additional species of Sundew in Florida: *D. capillaris*, which grows in boggy ponds, and bears pale, rose-colored flowers, and *D. brevifolia*, — a pretty little plant with rather large white flowers, — found in the damp Pine-barrens. Both of these plants have the same fly-catching habits. There is still another species, the Slender Sundew (*D. linearis*), with which I am not familiar. This grows about the shores of Lake Superior. These are all of the Sundews, so far as I know, in our country.

The Venus's Flytrap (*Dionæa muscipula*) is one of the most singular and wonderful plants in the world. It belongs to the Sundew family. But, while quite different from these plants, it is more nearly related to them than to any others, so that botanists, not knowing what else to do with it, have placed it here. It is found only in the eastern part of North Carolina and in the adjacent parts of South Carolina. It grows in sandy bogs in the low Pine-barrens. The illustration (Fig. 49),

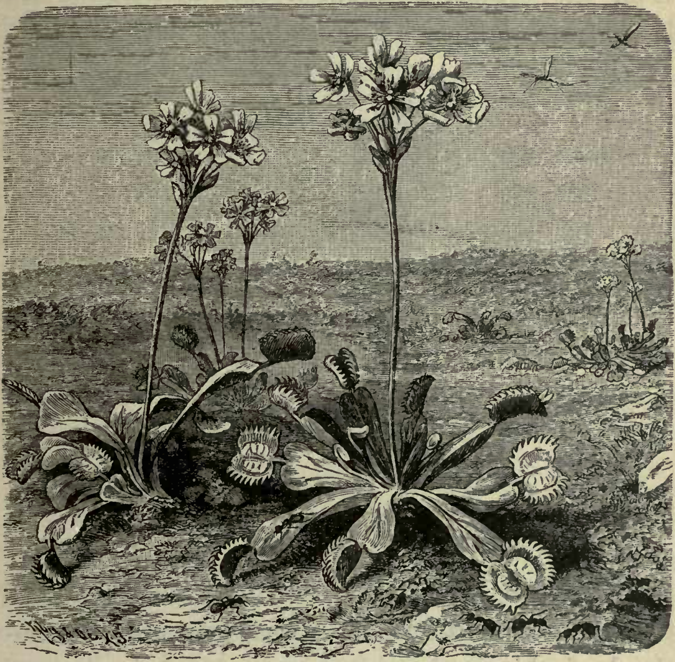

FIG. 49. VENUS'S FLYTRAP (Dionæa muscipula). ("Pflanzenleben.")

although reduced in size, shows how singular it is. The curious leaves are all at the base of the plant close to the ground. The flower-scape arises from the centre, is about a foot in height, and bears from eight to ten pretty white flowers.

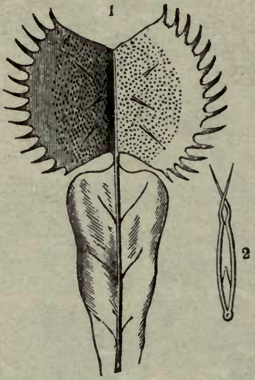

FIG. 50.

1. Outspread Leaf of Venus's Flytrap. 2. Section through a Closed Leaf. ("Pflanzenleben.")

This novel Flytrap has no sticky secretion, like the Sundews, with which to capture prey, but instead of this its leaves are converted into traps something like a steel trap. The midrib or central vein, which is thick and strong, divides the leaf into two lobes, each of which is furnished with three very sensitive, short hairs or filaments, as may be seen in the illustration of the single leaf (Fig. 50).

If either of these filaments is touched, the two lobes fly together instantly, and the stout bristles on the edge of the leaf interlock after the fashion of a steel trap.

Now when an unwary insect alights on a leaf-trap, which nature has set, it is sure to touch one or more of the sensitive filaments and is caught, and unless it is large and strong it cannot escape. Strong beetles and the stronger flies will force their way out between the bristles, but the weaker ones are held as if in a vice, and are soon enveloped in a slimy secretion, which at once begins to exude from the inner surface of the trap, and after several days digests all of the soft parts, when the leaf slowly opens, and, if it is still healthy, is now ready for another victim.

In my experiments, I have found that the Sundews digest their prey more quickly than the *Dionæa.* But I have worked with only cultivated plants; it may be different with those growing in their native bogs, which I hope some of my young readers may be able to investigate.

The Pitcher-plant (*Sarracenia purpurea*) (Fig. 51) is another remarkable Flytrap quite common in bogs from New England to Florida. It is a handsome plant; both its leaf and flower are curious and beautiful.

On large plants the leaves are from six to eight

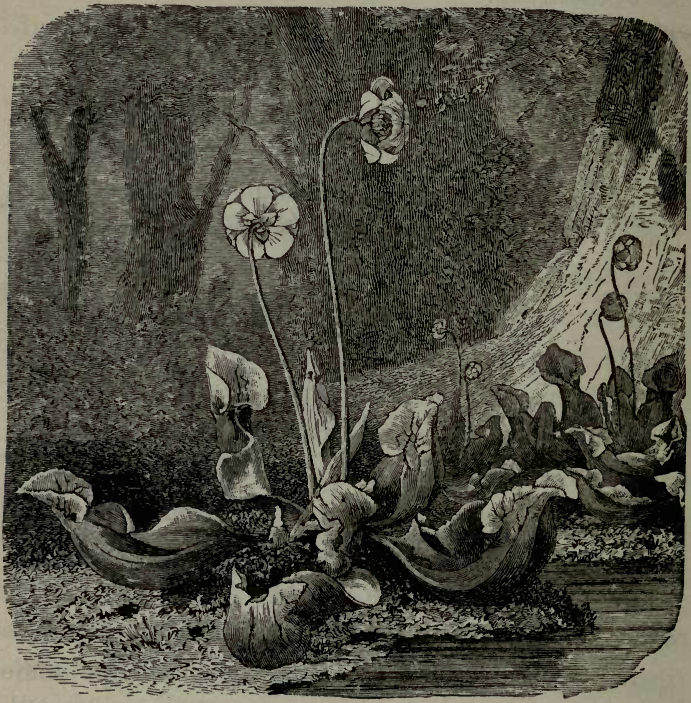

FIG. 51. PITCHER-PLANT (Sarracenia purpurea). ("Pflanzenleben.")

inches in length, and the flower-scape is a foot or more in height, bearing at the top a single, large, dark, purple flower. The singular fiddle-shaped petals are arched over the expanded umbrella-shaped style in a strange manner. The leaves grow in the form of fanciful pitchers, and hold water and usually many drowned insects.

I have observed this species closely, but have never been able to find what it is that attracts so many insects into the pitchers. I am satisfied, however, from repeated experiments, that there is something. I have large, strong plants growing in an artificial bog near the house, where I can conduct experiments at my leisure. When the new leaves have fully expanded, I set bottles (which have about the same breadth of mouth as the leaves, and will hold about the same amount) partly filled with clear water by the side of some of the plants, and these bottles do not capture any insects. Other bottles of the same capacity, partly filled with sweetened water and set near the leaves, invariably captured as many insects as the leaf-pitchers, and yet I could not detect any luring bait about these leaves; but the insects must find something or they would not enter into them any more than they would into the bottles of clear water.

There is a Pitcher-plant (*S. variolaris*) which grows in the South, that has a tempting bait extending from the base of the leaf to the top, and this is another reason I have for thinking that our Northern species must have some similar contrivance — but in a lesser degree — to lure insects into its cups.

The leaves of this Southern species are straight tubes, somewhat trumpet-shaped, standing erect, and are from twelve to fifteen inches in length. A hood or arch covers the top so that it is almost impossible for water to enter them. The flowers are yellow, but shaped like our purple ones. It captures great numbers of insects, which are attracted by the sweet, sugary secretion which extends along the entire length of the leaf and around the upper edge of the opening or mouth of the tube. As far as I have observed, the insects which partake of this secretion always go inside of the tube or pitcher and never return.

There is a difference of opinion among observers with regard to the action of the sweet secretion on the insects which partake of it. I have given my observations and experiments quite fully in "Home Studies in Nature,"[1] and have no reason to modify in the least my views as therein stated.

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[1] "Home Studies in Nature." By Mary Treat. Harper & Brothers. 1871.

And here is a good field for the young observer to make careful experiments, in order to settle the question with regard to the action of this secretion on the various insects which feed on it, and to determine why they do not get out of the pitchers.

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